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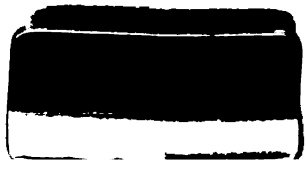

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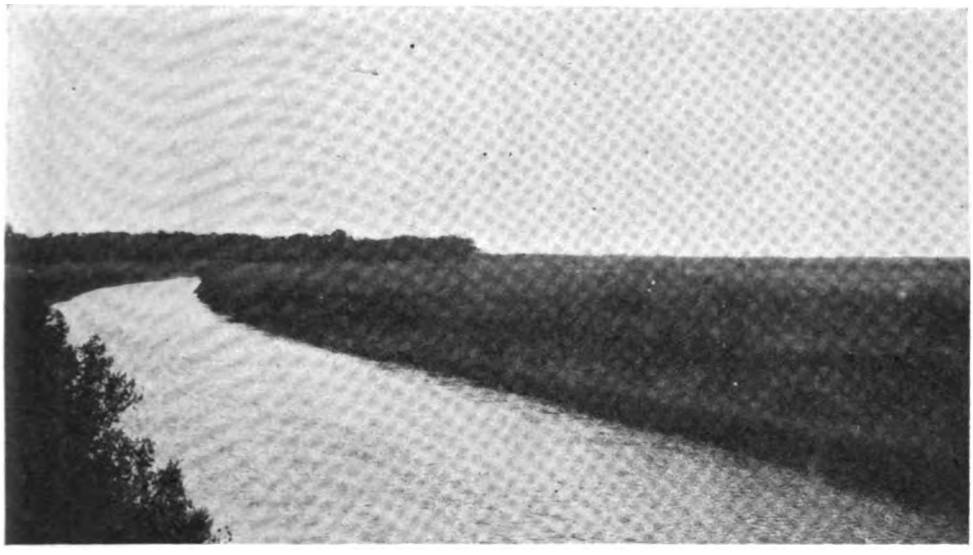
June, 1922 Soil Survey Report No. 22

SOIL SURVEY OF IOWA

Report No. 22 PALO ALTO COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of A. M. O'Neal, Jr., L. W. Forman and W. G. Baker



These bottomland soils are in the Cass series.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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PALO ALTO COUNTY SOILS*

W. H. Stevenson and P. E. Brown, with the assistance of A. M. O'Neal, Jr., L. W. Forman and W. G. Baker.

Palo Alto county is located in the second tier of counties from the Minnesota state line and in the fourth tier east of the Nebraska state line. It is entirely within the Wisconsin drift soil area and its soils are therefore all derived from this material, either in its original location on the uplands or as it has been carried by the streams and reworked and deposited on the terraces and bottomlands.

Palo Alto county has an area of 561 square miles or 359,040 acres. Of this area 326,821 acres, or 91.0 percent, is in farm land. The total number of farms is 1,743 with an average size of 187 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land of the county:

Acreage in general farm crops	268,799
Acreage in pasture	66,070
Acreage in farm buildings, feed lots and public highways	17,336
Acreage in waste land	3,562
Acreage in crops not otherwise listed	194

The type of agriculture practiced in Palo Alto county at present is very largely general farming, with some raising and feeding of hogs and beef cattle and some dairying. The income of the county is derived partly from the sale of corn and oats and partly from the sale of hogs, beef cattle and dairy products. The livestock industry and the dairy industry are gradually becoming more important and the amount of corn and oats sold out of the county is decreasing as these crops are more largely fed. At present a large part of the corn crop and probably two-thirds of the oats crop are used for feed on the farms.

There is a considerable area of waste land in the county and it is very important that some method of treatment be adopted which will permit of the reclamation of these areas. General recommendations for the treatment of such soils cannot be given because the causes of infertility are various, and treatments needed in one case would be of little or no value in other instances. Special treatments which will prove valuable under individual soil conditions will be mentioned later in this report. Advice regarding treatments most desirable in special cases may be obtained from the Soils Section of the Agricultural Experiment Station upon request.

The general farm crops grown in Palo Alto county in the order of their importance are corn, oats, hay, potatoes, barley, wheat, alfalfa, and rye. The average yield and value of these crops in 1920 are given in table I.

Corn is by far the most important crop, both in acreage and value. It is grown in all parts of the county and average yields of 45 bushels per acre are secured. This yield is considerably higher than the average for the state and apparently the soil conditions are quite satisfactory for the growth of this crop. A large part of the corn produced in the county is fed to cattle, hogs and work stock on the farms. Some is utilized for ensilage and the remainder is either

*See Soil Survey of Palo Alto County by A. M. O'Neal, Jr., of the United States Department of Agriculture, and F. M. Russell, C. E. Watts and G. H. Artis of the Iowa Agricultural Experiment Station.

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TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN PALO ALTO COUNTY, IOWA.

Crop	Acres	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	140,000	42.8	45.0	6,300,000	$0.47	$2,961,000
Oats	89,300	27.3	43.0	3,839,900	0.36	1,382,364
Winter wheat	0	.....	....	.....	....	.....
Spring wheat	840	0.2	13.0	10,900	1.35	14,715
Barley	1,370	0.4	27.0	36,990	0.63	23,303
Rye	430	0.1	19.0	8,170	1.17	9,558
Hay (tame)	17,325	5.3	1.2	20,790	16.24	337,143
Hay (wild)	18,760	5.7	1.1	20,636	12.69	261,870
Alfalfa	180	0.05	3.5	630	19.23	12,014
Potatoes	594	0.1	119.0	70,686	1.22	86,236
Pasture	66,070	20.2	....	.....	....	.....

sold to local elevators for shipment to outside markets or is shipped direct by the grower. Chicago is the principal market.

Oats is the second crop in the county in acreage and in value. It is grown on practically every farm and average yields of 43 bushels per acre are secured. Most of the oats produced is fed on the farms, the remainder, probably amounting to about one-third of the crop, being sold to elevators and shipped to outside markets.

Rather a considerable area in the county is devoted to hay and the value of the tame hay and the wild hay produced is considerable. Wild hay is produced on a somewhat larger area than the tame varieties, nearly all the river bottomland and the poorly drained areas along the streams being devoted to this crop. Practically all of the wild hay crop is baled and shipped. The tame hay consists either of clover and timothy mixed or of timothy alone, and average yields of 1.2 tons per acre are secured. Some clover is grown alone, in which case it is usually seeded with oats as a nurse crop. The general practice followed in handling clover or clover and timothy mixed is to utilize it to some extent for pasture the same year the grain crop is harvested. The next year the clover is cut twice for hay. A few farmers make only one cutting and turn the second crop under as a green manure. This practice is very desirable for improving the soil condition. Where timothy is grown the land usually remains in hay for several years. Practically all of the tame hay produced on the farms is used in feeding the work stock and beef cattle.

Potatoes are grown to some extent and rank fourth in crop value in the county. Average yields of 119 bushels per acre are secured and in 1920 the total production amounted to over 70,000 bushels. Small areas are devoted to this crop on practically every farm and the entire production is utilized for home use or sold at local markets.

Barley is grown on a number of farms in the county and the total value of this crop is considerable. Most of it is used for feeding hogs, altho a small portion is sold at the local elevators. Average yields of 27 bushels per acre are secured.

Spring wheat is grown on a small area and average yields of 13 bushels per acre are obtained. It is all sold and shipped to Chicago.

Alfalfa is grown on a small acreage in an experimental way and very satisfactory yields are secured. The value of this crop is considerable and it will

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undoubtedly be grown much more extensively after its desirability is more widely recognized. With proper care in preparing the soil, liming, inoculating and selecting the seed, there should be no difficulty in securing a satisfactory growth under the conditions in this county.

Rye is grown on a small area in the county and is relatively unimportant. Flax is produced to some extent, being planted on sod ground and generally utilized the first year on reclaimed swamp and bottomland. All of the flax seed produced is shipped out of the county, chiefly to Minneapolis. A small area is devoted to popcorn, but most of this product is used locally. Sweet corn, millet, sorghum and sugar beets are crops of minor importance in the county.

Apple orchards are maintained on most farms but yields are not very satisfactory. Apparently little care has been taken of the apple trees. Strawberries and all kinds of garden crops are grown thruout the county and help to supply the home demand.

THE LIVESTOCK INDUSTRY IN PALO ALTO

The livestock industry of the county includes the raising and feeding of hogs and beef cattle, and dairying. A few sheep are kept, but this is not an important industry. The poultry industry has developed to some extent and there is a rather considerable income from the sale of poultry and eggs.

The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the character and extent of the livestock industry in Palo Alto county:

Horses, all ages	11,008
Mules, all ages	467
Swine on farms July 1, 1920	60,479
Swine on farms, Jan. 1, 1921	48,308
Cattle (cows and heifers kept for milk)	10,389
Cattle (other cattle not kept for milk)	19,888
Cattle (all ages)	30,277
Sheep (all ages on farms Jan. 1, 1921)	3,945
Sheep (shipped in for feeding, 1920)	1,446
Sheep (total pounds of wool clipped)	15,352
Poultry (total number on farms Jan. 1, 1921)	211,480
Poultry (number dozen eggs received 1920)	666,323

Hogs are raised on practically every farm and this is the principal livestock ndustry in the county. The number of hogs per farm varies from 60 to 100 ead. There are a few breeders of purebred stock, as well as a few who raise nd feed hogs on an extensive scale. The most popular breeds are the Duroc ersey, Chester White, Poland China and Hampshire. The home and local arkets are supplied by the hogs raised in the county and there is a large sale ither by the growers or by the buyers to the Chicago markets.

Dairying is a rather important industry in the county and in 1920 there were cooperative creameries. The income from the sale of dairy products, exclusive f home use, was estimated in 1920 at almost half a million dollars. Dairy herds sually contain from 6 to 20 cows. The Holstein and Jersey cattle are preferred, ltho grades of these are the most common. Many of the farms are equipped ith silos.

On a number of the farms small herds of beef cattle are maintained and a ew animals are fattened each year for the market. Some feeders are shipped nto the county from Omaha and Sioux City, fed a few months and then shipped

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to Chicago. Favorite breeds of beef cattle on the farms are Shorthorns and Aberdeen Angus.

At the present time there are only a few flocks of sheep in the county. Some western sheep are bought and turned into the corn fields to forage until cold weather and are then sold and shipped. Poultry products are providing considerable income on the farms. A few horses and mules are raised, largely for supplying the home demand.

LAND VALUES

The value of land in Palo Alto county is extremely variable, depending upon many factors, such as location, drainage, topography and the improvements on the farms. The average value of farm land in 1920 was about $200 per acre. Along the river where the drainage is poor, the price ranges from $75 to $125, while in other sections where the land is improved, the value ranges from $175 to $200. Well improved farms located near the principal towns are valued at $250 per acre. More recently prices of improved farm land have gone even higher.

DRAINAGE IS NEEDED ON MANY FARMS

Crop yields in Palo Alto county are in general fairly satisfactory, but in many cases larger crops would be secured if better methods of soil treatment were practiced. There are many cases where drainage is unsatisfactory and satisfactory crop yields are impossible. The first treatment needed to bring many of the soils of the county up to a high state of production is tiling and ditching. Many farmers have reclaimed considerable areas by straightening and deepening the channels of various creeks, by cutting ditches and by laying tile lines. The county has aided in this work by straightening and deepening the channels of the river. There is still much land, however, which is not being utilized for the growing of general farm crops owing to its lack of adequate drainage. The expense involved in draining these areas is frequently considerable, but the value of the crops produced after such land is drained more than makes up for the outlay.

A few of the soils of the county are acid and in need of lime, but many of them are well supplied with lime and in some cases so well supplied that there should be no need of applying this material for many years to come.

PALO ALTO SOILS ARE GENERALLY FERTILE

The soils of the county are quite generally high in organic matter and high in nitrogen and there is not the great need for applications of manure that is evident in so many parts of the state. Small applications of farm manure, however, would be of value on newly drained reclaimed land in order to stimulate available plant food production. Large applications of this material are not needed on most of the soils of the county. Care should be taken, however, to keep up the supply of organic matter in the soils and when they are brought under cultivation the utilization of farm manure in small amounts at regular intervals is a very necessary practice.

PHOSPHORUS CONTENT OF SOILS IS NOT HIGH

The phosphorus content of the soils of the county is not high in any case and neither is it extremely low. There is a possibility, therefore, that phosphorus

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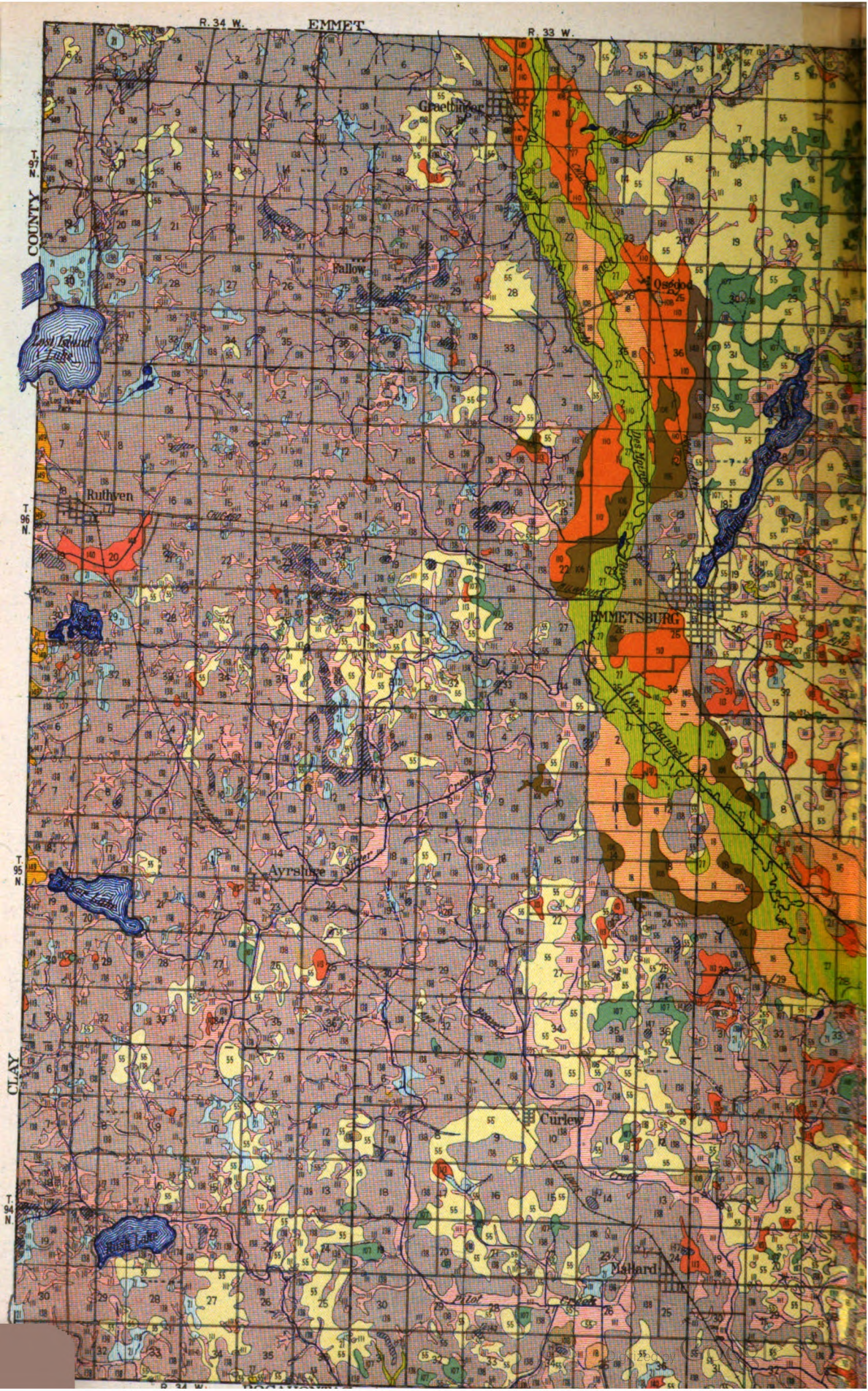
R. 34 W.
EMMET
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Graettinger
Ellsworth
Ossian
Lost Island Lake
Ruthven
EMMETSBURG
Ayrshire
Curlew
Mallard
T. 97 N.
T. 96 N.
T. 95 N.
T. 94 N.
CLAY

At all events, s the crop pro- with the use of nt time, and if at material may ofit. It may be imed land and better physical rns. This is a xperiments now when the results he problem will s and from the strongly to the farm crops.

the soils of the these materials ured from their chase, there can . It should be pared with phos- e made.

UNTY

y are so deeply influence what-

over the county ere left behind. e surface of the ansan sand and face of this drift , the Wisconsin, depth ranging e to the varying apsed after the he Kansan drift eristic color and and impervious ne sand, pebbles color of the drift sand and gravel as the Buchanan

gravel which are g the retreat of ainage channels,

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fertilizers may prove of value in some cases at the present time. At all events, these materials will be needed in the near future, especially as the crop production on the soils is increased. Tests on individual farms with the use of rock phosphate or acid phosphate are recommended at the present time, and if either of these materials show profitable crop increases, then that material may be applied to large areas on the farm with the assurance of profit. It may be that acid phosphate will prove more profitable on newly reclaimed land and later when decomposition processes are more vigorous, owing to better physical soil conditions, rock phosphate may give more profitable returns. This is a question which can only be settled by special tests. Field experiments now under way in the county include tests of these materials and when the results of these tests become available it is hoped that the solution of the problem will be provided. The indications from the greenhouse experiments and from the field tests in other counties on the same soil types point very strongly to the need of phosphorus fertilization for the best growth of general farm crops.

Complete commercial fertilizers are probably unnecessary on the soils of the county at the present time but field tests may include the use of these materials and they may show value in some cases. When the returns secured from their use are sufficient to warrant the expense involved in their purchase, there can be no objection to the use of complete commercial fertilizers. It should be emphasized, however, that such materials should always be compared with phosphorus fertilizers if satisfactory economic comparisons are to be made.

THE GEOLOGY OF PALO ALTO COUNTY

The rock formations underlying the soils of Palo Alto county are so deeply buried under the subsequent deposits of drift that they exert no influence whatever upon the soils of the county and need not be considered.

At least twice during the glacial age great ice sheets swept over the county and upon their retreat vast deposits of glacial drift or till were left behind. The earlier glaciation, known as the Kansan, covered the entire surface of the land, burying the original bed rock and the covering of pre-Kansan sand and gravel found occurring infrequently over the surface. The surface of this drift deposit was considerably modified by the time the later glacier, the Wisconsin, appeared. The Kansan drift deposit is extremely variable in depth ranging from 1 to 300 feet and this variation in depth is probably due to the varying erosive action which occurred during the centuries which elapsed after the deposition and before the invasion by the Wisconsin glacier. The Kansan drift material is generally known as blue clay, indicating the characteristic color and texture of the unweathered material. It is extremely tough and impervious and is made up of a fine-grained compact clay containing some sand, pebbles and boulders of various sizes and shapes. When weathered the color of the drift changes to a yellow or reddish-yellow. The older deposits of sand and gravel which are occasionally found beneath the blue clay are known as the Buchanan gravels and they extend for a depth of 20 feet.

Above the Kansan blue clay there appear layers of sand and gravel which are known as the Wisconsin gravels. These were deposited during the retreat of the Wisconsin glacier, particularly in the old valleys and drainage channels,

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and may now appear at a considerable distance from the present drainage system, in isolated mounds on the sides of hills or in low ridges on level plains. These gravel deposits have been covered by the heavier material of the typical Wisconsin drift and while they occasionally are sufficiently near the surface to influence the character of the soil, in general the covering of the Wisconsin drift deposit is so deep that the gravels are not encountered in the three foot section.

The Wisconsin glacier descending from the northwest covered the entire area of the county and left behind a deposit which at the present time varies from a few inches to 80 feet or more in thickness. On the tops of hills, where erosion has occurred, the drift deposit is quite thin, while in the more level portions of the county the deposit extends for many feet.

The Wisconsin drift is a mixture of boulders, sand, silt and clay. A few large limestone boulders are found, but the principal part of the limestone occurs in a finely divided state. Surface boulders, sometimes 3 to 4 feet in diameter, are found on the lower gentle slopes and thruout the flatter areas. During the time which has elapsed since its deposition, much of the lime content, and in many cases practically all, has been leached out of the soil. The surface soils of the county are frequently acid, but in most instances lime is found in considerable amounts in the lower soil layers .

The original drift material was yellowish or buff colored and even occasionally whitish in color. During the ages which have elapsed since the glacier retreated, there has been an accumulation of organic material in the surface soil and under the characteristic topographic conditions in the county, this accumulation has been particularly rapid and the burning out of organic matter and leaching have been slow. The surface soils, and in many cases the subsurface soils of the county are dark brown or even deep black in color. The lower layer or subsoil is usually the typical grayish or yellowish color of the original Wisconsin drift. In the western part of the county, the topographic conditions give evidence of being the location of the terminal moraine of the glacier. There is no distinct indication of this moraine as far as the soil types are concerned, but the topography is distinctly morainic. It is in this part of the county that the Wisconsin drift deposit is of the greatest depth. Many of the hills are made up entirely of Wisconsin drift, the deposit extending for many feet below the base of these hills. The upland soils of the county are derived entirely from the Wisconsin drift and they are classed in the Clarion and Webster series.

PHYSIOGRAPHY AND DRAINAGE

In topography Palo Alto county is generally gently undulating to rolling. It consists of a broad drift covered plain whose surface has been only slightly modified thru erosion because of a rather indefinite drainage system.

In the four northeastern townships and in the southeastern townships lying to the east of the West Fork Des Moines river, the topography ranges from gently undulating to rolling and there are low hills rising from the broad flat plains of the Webster upland.

West of the river the topography becomes more rolling and in the extreme western part of the county the surface is more or less irregular and is made up of a succession of hills and depressions. In the northwestern part of the county,

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along the Emmet county line, the topography becomes rough and broken and many of the hills rise to a height of 50 to 100 feet. Here, too, the slopes are steeper and the hills more sharply defined than in the remainder of the morainic area. Similar rather rough areas are found in the southeastern section of Highland township, in the northeastern sections of Silver Lake township, and in the southwestern sections of Walnut township. In these rougher areas, indicating what is known as the morainic topography, there are areas of a gravelly subsoil phase of the Clarion loam, a type which may be considered to indicate morainic conditions.

Narrow strips of rough broken land extend on both sides of the West Fork of the Des Moines river and Jack creek in the vicinity of Graettinger. In these areas also the soil type is the gravelly subsoil phase of the Clarion loam.

The more or less undulating to rolling topography which is characteristic of the county in general is broken by the broad first bottoms and narrower second bottoms developed along the West Fork Des Moines river and the larger creeks, and by the narrower bottoms which are found along the smaller streams and

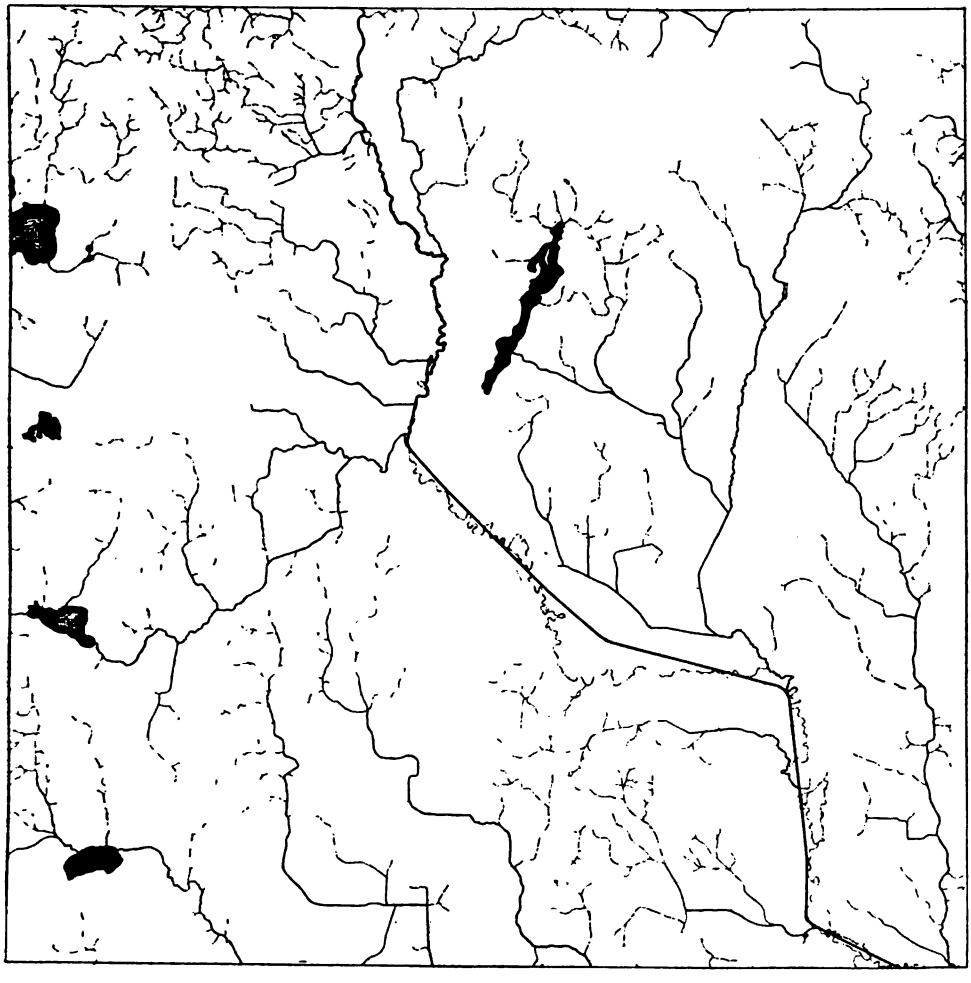

Fig. 1. Natural drainage system of Palo Alto county.

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intermittent drainage-ways. There are also many undrained depressions in the level upland where peat has accumulated. Practically all of these were probably originally lakes and ponds. At the present time many of them have been drained and the land is slowly being brought into a condition suitable for cultivation. Many of the peat areas may still be considered ponds, particularly under abnormal seasonal conditions. In the western part of the county four lakes of considerable size remain, and extending north from Emmetsburg there is a large lake known as Medium lake. Lost Island lake is the largest lake in the county and Silver lake, Rush lake and Virgin lake are smaller than the two already mentioned.

The drainage of the county is carried mainly by the West Fork Des Moines river which flows in a southeasterly direction across the county. A small area in the northwest corner of the county is drained to the west into the Little Sioux river. The main tributaries of the West Fork Des Moines river are Jack creek, Cylinder creek, Prairie creek, Beaver creek, Pilot creek and Silver creek. The first three of these drain the area east of the river and the remaining three drain the southwestern portion of the county, Pilot creek and Beaver creek joining the river in Pocahontas county to the south.

The flood plain of the West Fork Des Moines river lies from 50 to 100 feet below the uplands. Near Graettinger there are sharp river bluffs, but thruout the remainder of its course across the county, the river has banks which are characterized by an even gentle slope. It varies in width from 30 to 80 feet and meanders back and forth thruout the bottoms, making new channels from year to year. The drainage system of the county is quite inadequate, as will be evidenced from an examination of the drainage map. Considerable areas are not connected by natural drainage channels with the river and there are many depressions and low pond areas which do not have any natural outlets.

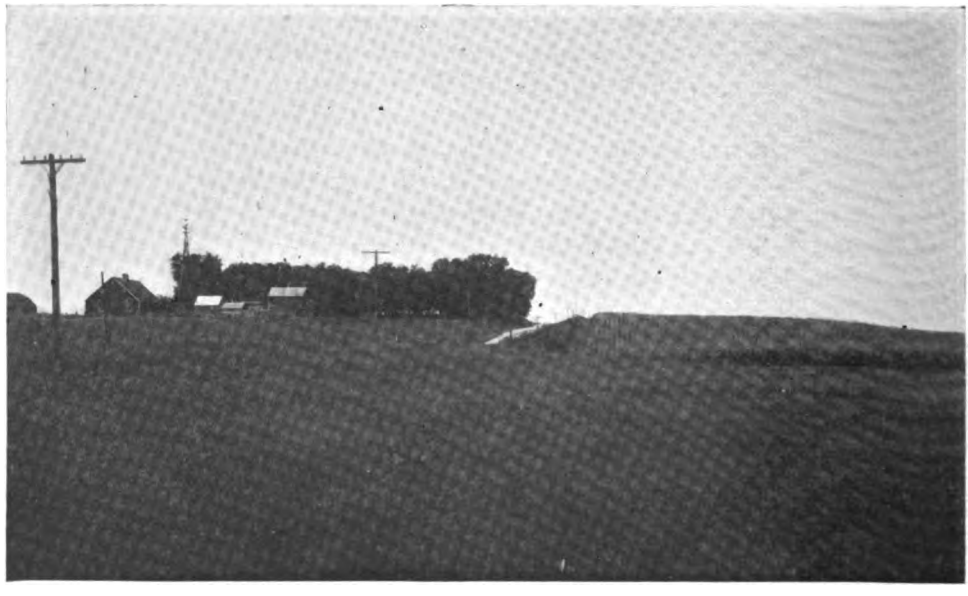

Fig. 2. Clarion loam topography near Ruthven.

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Drainage conditions have been considerably improved in recent years by straightening and deepening the channels of some of the creeks, by cutting ditches and by the installation of tile. Many farms have been thoroly tiled and drained, but there are still considerable areas in which drainage is very necessary if satisfactory crops are to be grown. An examination of the soil map will indicate the spotted conditions of the uplands and in many cases these small areas scattered over the surface of the land indicate poor drainage. This is particularly true in the north central portion of the county where the Webster silty clay loam is found in small scattered areas thruout the Webster loam upland. The same condition is evidenced in the western part of the county where there are many small areas of peat, Webster silty clay loam, and Lamoure silty clay loam scattered thru the Clarion loam upland. Drainage is undoubtedly one of the most important treatments necessary for the development of a higher state of fertility and greater crop production for the soils of this county.

SOILS OF PALO ALTO COUNTY

The soils of Palo Alto county are grouped into three classes according to their origin and location. These are drift soils, terrace soils, and swamp and bottomland soils.

Drift soils are those deposited by glaciers upon their retreat and they contain material from various sources and usually pebbles and boulders.

Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams by which they were formed or by a deepening of the river channels.

Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow. The total acreage and percent of the area of the county included in each of these three groups of soils are shown in table II.

Almost three-fourths of the total area of the county, 70.6 percent, is covered by the drift soils. The terrace soils are found only in small areas and make up only 3.3 percent of the total area of the county. The remainder of the county, 26.1 percent, is covered by swamp and bottomland.

There are 12 individual soil types in the county and these together with the gravelly subsoil phase of the Clarion loam and the areas of peat and muck make up a total of 14 separate soil areas. There are seven drift soils, including the phase of the Clarion loam, two terrace types and five areas of swamp and bottomland, including peat and muck. These various soil types are distinguished on the basis of certain definite characteristics which are described in the appendix to this report. The names which are given to the various types indicate

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN PALO ALTO COUNTY.

Soil Group	Acres	Percent of total area of county
Drift soils	253,760	70.6
Terrace soils	12,032	3.3
Swamp and bottomland soils	93,248	26.1
	359,040	....

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quite definitely certain group characteristics. The areas of the various soil types in the county are shown in table III.

The Clarion loam is the largest individual soil type in the county and together with the gravelly subsoil phase it covers 37.7 percent of the total area. The Webster loam is almost as extensive at the Clarion loam, covering 28.0 percent of the total area of the county. These two soil types compose about two-thirds of the area of the county and are therefore the most important.

The Webster silty clay loam, the third upland drift type, is of very much smaller extent, covering 2.8 percent of the total area of the county. The Webster silt loam is likewise small in extent, covering only 1.7 percent of the total area. The Clarion fine sand, the Rogers silt loam and the Clarion fine sandy loam are all very small in area, covering 0.2, 0.1, 0.1 percent of the county, respectively. The terrace soils are both minor in extent, the O'Neill fine sandy loam covering 1.7 percent of the total area and the O'Neill loam 1.6 percent of the county.

The Lamoure silty clay loam is the most extensive bottomland type and is the third largest soil type in the county, covering 14.4 percent of the total area. The Wabash silty clay, the second largest bottomland soil, is very much smaller in area, covering 3.8 percent of the county. The Cass loam is slightly smaller than the Wabash silty clay, covering 3.6 percent of the county.

There are numerous small areas of peat and muck and the total area of these materials in the county amounts to 2.8 per cent.

The Cass silt loam is the smallest bottomland type and it is of minor importance, covering only 1.5 percent of the total area of the county.

The upland soils of the county are generally somewhat undulating to rolling in topography. This is particularly true in the eastern and southern part of the county. West of the river, however, and particularly in the northwestern part of the county, the topography becomes more distinctly rolling and in some cases even somewhat rough and broken. The Webster soils are quite generally level to gently undulating in topography while the Clarion loam varies from an undulating to a strongly rolling topography. This is the upland type which is

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN PALO ALTO COUNTY, IOWA.

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
138	Clarion loam	132,992	37.7
147	Clarion loam (gravelly subsoil phase)	2,624	
55	Webster loam	100,352	28.0
107	Webster silty clay loam	9,984	2.8
113	Webster silt loam	6,272	1.7
148	Clarion fine sand	576	0.2
140	Rogers silt loam	512	0.1
149	Clarion fine sandy loam	448	0.1
	TERRACE SOILS		
110	O'Neill fine sandy loam	6,144	1.7
108	O'Neill loam	5,888	1.6
	SWAMP AND BOTTOMLAND SOILS		
111	Lamoure silty clay loam	51,648	14.4
27	Wabash silty clay	13,632	3.8
18	Cass loam	12,736	3.6
21	Peat and muck	9,920	2.8
106	Cass silt loam	5,312	1.5
	Total	359,040	....

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found in the more hilly section in the northwestern part of the county. Particularly in areas where the gravelly subsoil phase of the Clarion loam occurs, the topographic condition becomes strongly rolling to rough and broken. The topography of the Clarion fine sand is gently rolling while the Clarion fine sandy loam occurs on low ridges and hills. The terrace and bottomland types are all level to flat in topography.

The terrace types of the O'Neill series are very adequately drained, due of course to the sandy character of the subsoil. The upland types of the Webster series, particularly the silty clay loam, are in need of drainage and some portions of the silt loam, the loam, and the Clarion loam are likewise in need of drainage. The lighter textured upland types are quite satisfactorily drained. The bottomland soils of the Wabash and Lamoure series are in need of drainage. The Cass loam and the Cass silt loam also are often in need of drainage, even tho the subsoil is sandy, owing to the mucky character of the surface soils. All the bottomland types are, of course, subject to overflow and hence the drainage problem with these soils is particularly important. Besides adequate drainage of the bottomland types they should also be protected from overflow if good crops are to be grown.

The topographic conditions in the county, both in connection with the upland types and with the bottomlands, give evidence of the need of artificial drainage over considerable areas. The installation of tile and in some cases the use of ditches is very necessary if the soils of the county are to be made properly productive.

THE FERTILITY IN PALO ALTO COUNTY SOILS

Samples were taken for analyses from each of the soil types in Palo Alto county, with the exception of the Clarion fine sandy loam and the gravelly subsoil phase of the Clarion loam. The areas of peat and muck likewise were not sampled. The more extensive types were sampled in triplicate, while in the case of the minor types only one sample was taken.

All the samples were drawn so that they should be thoroly representative of the particular soil types and that all variations due to local conditions or special treatments should be eliminated. The samples were drawn at three depths, 0″ to 6 2/3″, 6 2/3″ to 20″, and 20″ to 40″, representing the surface soil, subsurface soil and subsoil, respectively.

Analyses were made on all samples for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were employed in the determinations of phosphorus, nitrogen and carbon, and the limestone requirement was determined by the Veitch method. The figures given in the tables are the average of the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated in pounds per acre on the basis of 2,000,000 pounds of surface soil per acre.

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TABLE IV. PLANT FOOD IN PALO ALTO COUNTY, IOWA, SOILS.
Pounds per acre of pounds of surface soil (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
138	Clarion loam	1,872	5,768	67,605	395	2,576
55	Webster loam	1,701	6,897	82,854	Trace	515
107	Webster silty clay loam	1,643	4,232	74,706	Trace	Basic
113	Webster silt loam	1,818	11,444	130,166	34,034	Basic
148	Clarion fine sand	1,589	2,186	27,600	0	3,091
140	Rogers silt loam	2,141	13,898	252,844	62,156	Basic
	TERRACE SOILS					
110	O'Neill fine sandy loam	1,690	5,506	66,800	0	3,091
108	O'Neill loam	1,784	4,876	63,000	0	4,250
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam	1,966	10,018	117,808	16,992	Basic
27	Wabash silty clay	2,478	7,930	97,168	432	Basic
18	Cass loam	1,616	7,902	98,400	0	386
106	Cass silt loam	1,737	12,132	142,756	844	Basic

The phosphorus supply in the various soil types in the county is remarkably uniform. There is a range in content from 1,589 to 2,478 pounds per acre. There is evidently no large occurrence of this element in any of the soils of the county but the supply is considerably larger than is the case in many of the lighter textured soils in other counties. Even in the Clarion fine sand, the type containing the least amount of any, the supply is only slightly less than in the Webster silty clay loam, which is ordinarily particularly well supplied with this element.

There is absolutely no relation between the phosphorus content of the soils and the various groups of soils. The terrace types are apparently about as well supplied as the bottomlands and the upland soils will average very much the same. Furthermore, there is very little opportunity to draw any conclusions regarding the relation of soil type to phosphorus supply. The Clarion and Webster soils of the upland are very similarly supplied with this constituent. The Clarion fine sand is somewhat lower than the loam. The Webster loam is somewhat lower than the silt loam. The O'Neill fine sandy loam shows less phosphorus than the loam and the Cass loam is lower in this constituent than the silt loam.

The differences in all these cases, however, are very small and, in fact, they hardly warrant conclusions except in so far as they verify evidence obtained in other counties to the effect that light textured types are usually lower in phosphorus than the heavier textured types of the same series.

In some cases there may be an exception to this general rule and such an exception appears in the results in table IV. The Webster silty clay loam shows a smaller amount of phosphorus than the Webster silt loam, which is contrary to what would usually be expected. However, the Webster silt loam in this county, according to these analyses, is a particularly rich type. It is extremely high in organic matter and nitrogen and this may explain, in part at least, the higher phosphorus content. Perhaps there is more organic phosphorus in this type. The Rogers silt loam shows the highest phosphorus content of any of the upland types. However, this is a rather unusual soil, having been formed in an old lake bed and being excessively high in organic matter and in carbonates. Again the

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high phosphorus content may be due to the occurrence of organic phosphorus. Probably in this case, however, the higher content is due to the fact that the soil has been cropped to a less extent and hence there has been a smaller removal of this constituent.

The Wabash silty clay and the Lamoure silty clay loam of the bottoms are higher in phosphorus than the soils of the Cass series. These are generally rich soils, being high in organic matter and in plant food. The surface soils of the Cass types in this county, however, are very much the same in composition as the surface soils of the Lamoure and Wabash as far as organic matter and nitrogen is concerned. They do seem to be slightly lower in phosphorus. This may be a condition due to the origin or particular nature of the soil or of the subsoil conditions. It is quite customary to assume that soils with sandy or gravelly subsoils are poorer in fertility and of less value, therefore, than soils with heavier textured subsoils. Occasionally, however, the former types may actually be much more profitably productive depending very largely upon seasonal conditions.

In general it seems evident from these analyses, that while the phosphorus supply is not extremely low, phosphorus fertilizers will need to be used on these soils in the rather near future if the soils are to be kept at the highest state of productivity. Even if the total amount present could be made available as rapidly as needed by crops, there is sufficient for only a limited number of years but as the supply of total phosphorus in the soil decreases there is a disproportionate decrease in available phosphorus. In other words, available phosphorus production in soils decreases much more rapidly than does the total supply. There is no means of determining accurately the rate of availability of the phosphorus in these soils but ordinarily it is believed that if the soil is well drained and cultivated and abundantly supplied with organic matter, the production of available plant food will occur sufficiently rapidly to supply the needs of growing crops. It may be, therefore, that available phosphorus is being produced in the soils of this county as rapidly as is necessary at the present time. The only way to determine whether or not this is true is to apply acid phosphate to a small area and if increased crop yields result from the application then it is certain that there is not sufficient available phosphorus being produced in the soil.

It would seem very desirable, therefore, that phosphorus fertilizers be tested on the soils of the county at the present time, to determine whether or not they will bring about increases in crops. Farmers may carry on a test on a small area on their farms and thus determine for their local conditions whether or not phosphorus is of value. An application of acid phosphate, for example, at the rate of 200 pounds per acre in the spring can readily be made to a portion of a field and if beneficial effects are noted then it may be certain that phosphorus fertilizers may be used to advantage on the particular soil.

THE NITROGEN SUPPLY

The nitrogen supply in the soils of the county is extremely variable. There is a range in this constituent from 2,186 to 13,898 pounds per acre. Apparently in most cases the soils are fairly well supplied with nitrogen, but in other instances the content is not large and the need for building the soil up in nitrogen

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content is evident. As in the case of phosphorus, there is apparently no relation between the nitrogen supply and the various soil groups except that the terrace types are lower in this constituent on the average than the other groups. This, however, is due mainly to the fact that the terrace soils are both of the O'Neill series and the low content of nitrogen may be attributed more to the characteristics of the particular soil series than to any characteristics of the soil group. The bottomland soils are somewhat richer in nitrogen than the average of the other groups of soils, as would be expected, inasmuch as the bottomland types have been very little used for cultivated crops and there has been very little washing away of the plant food and a smaller amount of decomposition of organic matter than commonly occurs in the upland types.

There is very little evidence of relationship between the soil texture and the nitrogen content. The Clarion fine sand is considerably lower than the Clarion loam, but the O'Neill fine sandy loam is higher than the O'Neill loam and the Webster silty clay loam is lower in nitrogen than the Webster loam. These latter figures indicate that there are other factors which are important in determining the nitrogen content of the soil than those which go to make up the texture or the series. The Cass loam is considerably lower in nitrogen than the silt loam, which would be expected, but the Lamoure silty clay loam and the Wabash silty clay are lower in nitrogen than the Cass silt loam, which might again be taken to indicate that the texture of the soil is only one of several factors controlling the nitrogen content. Ordinarily the Lamoure and Wabash series would be expected to show more nitrogen than the Cass series so that there is an exception here in the case of the Cass silt loam when a comparison is made on the series basis. The Clarion fine sand contains the smallest amount of nitrogen of any of the soils in the county, while the Rogers silt loam shows the highest content. This is the same relation as was evident in the case of phosphorus. The Webster silt loam is extremely high in nitrogen, unusually high in fact, for this particular type. In fact it contains almost as much nitrogen as the Rogers silt loam which is known to be rather an abnormal soil. The other upland types contain an average amount of nitrogen and very much the same content is shown by the terrace soils. The bottomland types are much better supplied with this constituent.

From the fact that the nitrogen content is not extremely low, it should not be concluded that nitrogen may be disregarded in considering systems of permanent fertility. It is very necessary on the upland soils of this county that the proper treatments be practiced to keep up the nitrogen supply and even to increase the amount of this constituent in some cases. Farm manures and crop residues return to the soil some of the nitrogen which has been removed by the growth of crops and these materials should be utilized in all cases in keeping up the nitrogen supply. In some instances it may be necessary to use leguminous crops as green manures in order to supplement the farm manure or to take the place of farm manure. It would be a comparatively simple matter to keep up the nitrogen content in those soils in which it is high at present and equally simple, by the use of farm manure, crop residues and leguminous green manures, to increase the nitrogen content in those soils which are not so abundantly supplied.

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In all soils under cultivation the relation between the content of nitrogen and of organic carbon is an indication of the rate of decomposition of the organic matter in the soils, or in other words, an indication of the production of available plant food. If the amount of organic carbon in relation to the nitrogen is reduced below a certain point, there is a decrease in the production of available plant food. In all cases in Palo Alto county the relation between these two constituents is such that there should be no question of a rapid production of available plant food. However, there are other factors involved in the case of these particular soils and the lack of drainage or inadequate removal of excess moisture which occurs in some cases, will prevent the most desirable rate of decomposition and hence will decrease the production of available plant food. When adequate drainage is insured in these soils, the chemical composition indicates that decomposition processes will proceed sufficiently rapidly to keep plants supplied with necessary food constituents.

There is usually a distinct relation between the nitrogen and organic carbon in soils and there is also a relation to the color of the soil. If the soil is light in color, it is low in organic matter and usually low in nitrogen. If it is black in color there is a large content of organic carbon and nitrogen is usually abundant. This relation holds true in the case of the Palo Alto county soils. There is a range in organic carbon from 27,600 pounds in the Clarion fine sand, up to 252,844 pounds in the Rogers silt loam. As in the case of nitrogen, the former type is the lowest of any in the county in carbon and the Rogers silt loam is the highest. The Cass silt loam, which is the second highest in nitrogen, is also second in organic carbon. The Webster silt loam which is third in nitrogen and only slightly lower than the Cass silt loam, is third also in the case of organic carbon and only slightly less in this constituent than the Cass silt loam. Similarly with the other soil types, the relations discussed in the case of nitrogen hold true in the case of organic carbon. Hence, as was noted in the case of nitrogen, there are no instances where the soils are alarmingly deficient in organic matter with the exception of the Clarion fine sand. In several of the soil types, however, the amount of organic carbon is not sufficient but that applications of farm manure would be of value. Furthermore, in practically all these types care must be taken to keep up the supply of organic matter or the soils will become deficient and crops will suffer.

Farm manure is the most important source of organic matter in soils. This material should be used on the soils of this county as far as it is available. All crop residues should be returned to the soils and there may be instances where leguminous green manure crops would be needed, particularly if farm manure is produced to only a limited extent and the soils begin to run down in organic matter and nitrogen content. It should be noted here also that in spite of the comparatively high content of organic matter in these soils, additions of farm manure give increased crop yields in practically all instances. Its beneficial effect may possibly be the result of the bacteria contained in the manure and may be attributed to a stimulation in the production of available plant food, but whatever the reason, the application of farm manure to these soils is known to increase crop growth and it will build up and keep up the supply of organic matter.

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Several of the soils in the county show a content of inorganic carbon, only three, however, showing any large supply of this constituent in the surface soil. The Webster silt loam, the Rogers silt loam and the Lamoure silty clay loam all seem to be very rich in inorganic carbon. Several other types show small amounts, but in no other case is the amount sufficient to prevent the surface soil from showing an acid reaction in the very near future. Three types in addition to the three showing a high content of inorganic carbon, give no limestone requirement. Two others show such a low lime requirement that they may almost be considered to be basic in reaction. Only in the case of two upland types and the O'Neill soils of the terrace group, is there any considerable lime requirement indicated by the tests.

The figures given in the table should be considered merely indicative of the needs of the particular soil types and tests should be made on these types in all cases before applications of lime are made. Even a much larger number of analyses than those reported here would not yield an accurate figure on the lime requirement of a soil type. Variations frequently occur even in the same soil type and no general average figures will serve to show how much lime should be added to any particular soil. If the proper amount of lime is to be applied, tests of the particular soils should be run and if the amount of lime, shown to be necessary according to the test, is used the best growth of all crops and particularly of legumes will be secured. Probably in the course of the next few years several of the types in this county which show a basic reaction at present will give a lime requirement when tested. This is owing to the rapid removal of lime from soils which occurs by utilization by plants and by leaching. Hence the soils of the county, even those which now show a basic reaction, should be tested for acidity at intervals during the coming years and when the test shows a lime requirement that material may be applied with the assurance of profit.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of sub-

TABLE V. PLANT FOOD IN PALO ALTO COUNTY, IOWA, SOILS.

Pounds per acre of four million pounds of subsurface soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
138	Clarion loam	3,609	7,640	94,400	0	4,121
55	Webster loam	3,196	9,153	114,171	829	Basic
107	Webster silty clay loam	2,936	9,080	117,706	Trace	Basic
113	Webster silt loam	2,747	9,864	117,700	49,100	Basic
148	Clarion fine sand	1,885	3,308	34,400	0	3,864
140	Rogers silt loam	3,637	47,268	518,272	130,528	Basic
	TERRACE SOILS					
110	O'Neill fine sandy loam	3,044	6,780	78,400	0	3,864
108	O'Neill loam	3,098	5,716	70,400	0	4,636
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam	2,774	5,940	83,648	26,752	Basic
27	Wabash silty clay	2,478	9,024	105,456	944	Basic
18	Cass loam	2,505	5,156	68,532	668	Basic
106	Cass silt loam	2,020	18,996	66,372	828	Basic

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TABLE VI. PLANT FOOD IN PALO ALTO COUNTY, IOWA, SOILS.

Pounds per acre of six million pounds of subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
138	Clarion loam	4,243	4,988	85,099	22,500	Basic
55	Webster loam	4,404	6,390	85,796	9,005	Basic
107	Webster silty clay loam	4,323	4,458	55,914	2,286	Basic
113	Webster silt loam	2,869	4,542	75,234	14,766	Basic
148	Clarion fine sand	5,010	1,680	25,800	0	2,319
140	Rogers silt loam	5,091	68,424	722,812	279,588	Basic
	TERRACE SOILS					
110	O'Neill fine sandy loam	3,535	3,402	39,000	0	1,158
108	O'Neill loam	3,839	1,848	26,400	0	3,577
	SWAMP AND BOTTOMLAND SOILS					
111	Lamoure silty clay loam	3,273	3,444	49,680	54,720	Basic
27	Wabash silty clay	3,273	5,550	84,606	1,794	Basic
18	Cass loam	3,111	2,814	37,020	3,180	Basic
106	Cass silt loam	2,828	1,596	22,002	1,398	Basic

surface and 6,000,000 pounds of subsoil per acre. The plant food content of the lower soil layers generally has very little effect on the fertility of the soil unless there is a very large amount of some one constituent present. In the soils of Palo Alto county there is no excessively large amount of any of the plant food constituents in any of the lower layers with the exception of the Rogers silt loam which, as has been stated, is manifestly an abnormal soil. The exact chemical composition of the lower soil layers is therefore of very little significance from the standpoint of determining the fertilizer requirements of the surface soils and these analyses will not be considered in detail.

The needs of the soils of the county as indicated in the case of the surface soils are very largely confirmed by the analyses of the lower soil layers. The phosphorus supply in these soils is not extremely high, neither is it very low. It seems evident, therefore, that phosphorus fertilizers will be needed at some time in the near future and they may also prove of some value at the present time in individual cases. The supply of organic matter and nitrogen is rather considerable in most of the types but it is apparent that for the continued fertility of these soils farm manure, crop residues and leguminous green manures will need to be utilized to keep up the supply of these constituents. In the subsurface soils only four of the types show an acid reaction, the two terrace soils and the Clarion fine sand and the Clarion loam. There is no large supply of lime in the subsurface, however, except in the same three types that showed a high content in the surface soil. In the subsoil, however, there are only three types which are not basic, the O'Neill terrace soils and the Clarion fine sand, and there is a rather considerable amount of lime present in nine of the soil types. The presence of lime in the subsoil, however, is of very little significance in determining the basic reaction of the surface soil. Lime rarely moves up in the soil and if the surface soil is acid it makes very little difference whether or not the subsoil is high in lime. The conclusions drawn in the case of the surface soils are not modified to any extent, therefore, by the analyses of the subsurface and subsoil samples and the recommendation regarding the testing of the soils in the county at the present time and at regular intervals in the future, should

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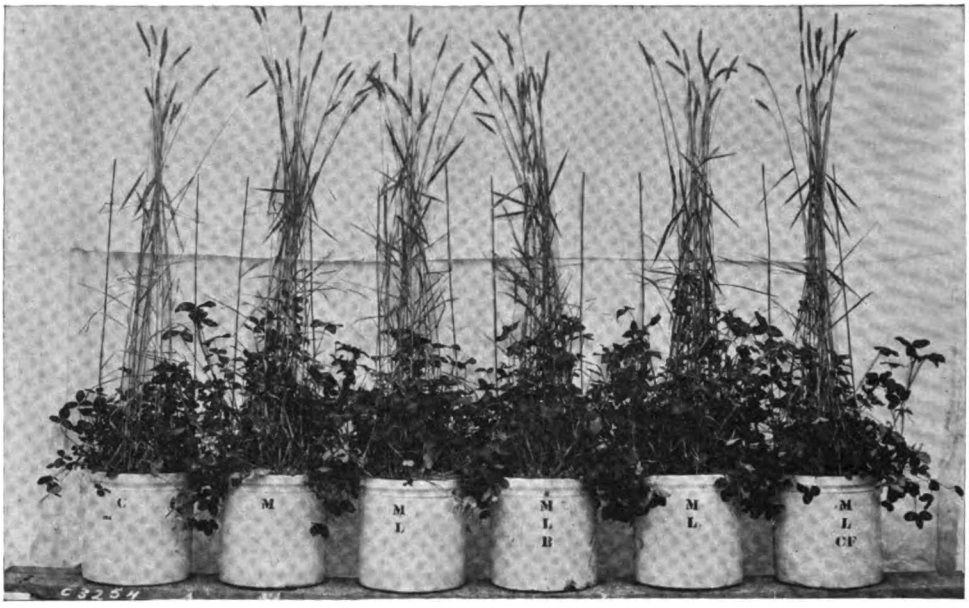

Fig. 3. Wheat and clover on Clarion loam.

be emphasized again. Only in this way can the farmer be sure that his soil is in the best reaction for crop growth and that he can secure a most satisfactory growth of legumes.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Palo Alto county in order to determine something regarding the fertilizer needs of the soils, and to get an idea of the value of the various fertilizing materials. These experiments dealt with two of the main soil types, the Clarion loam and the Webster silt loam. In addition to these two experiments, the results of the tests on the Webser silty clay loam in Buena Vista county are included because this type occurs in Palo Alto county also, and the results are undoubtedly applicable to that county.

The plan of all the experiments consisted in the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts used were the same as those employed in the field experiments and hence the results of these greenhouse tests may be considered to indicate roughly what would occur in the field. Manure was supplied at the rate of 8 tons per acre. Lime was added in sufficient amounts to neutralize the acidity as shown by the Veitch test and supply two tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments, clover being seeded about one month after the wheat was up.

The results of the experiment on the Clarion loam from Palo Alto county are given in table VII.

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TABLE VII. GREENHOUSE EXPERIMENT, CLARION LOAM, PALO ALTO COUNTY.

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	9.5	56.69
2	Manure	14.5	68.04
3	Manure+Lime	14.0	68.04
4	Manure+Lime+Rock phosphate	16.0	74.84
5	Manure+Lime+Acid phosphate	16.0	86.18
6	Manure+Lime+Complete commercial fertilizer	16.3	70.25

The effect of the applications of manure is shown very definitely in this table. Both the wheat and clover were increased in yield by the normal addition of manure.

The application of lime along with manure exerted no effect either on the wheat or clover. This particular soil sample was only very slightly acid in reaction and apparently did not need any lime. Other samples of the Clarion loam showing more of a lime requirement in the surface soils would undoubtedly need applications of lime and when the acidity is well developed in this type as frequently occurs, farm experience shows very definitely that the application of lime is necessary if the most satisfactory growth of legumes is to be secured.

The application of phosphorus fertilizers to this type seemed to give rather distinct crop increases, both for wheat and clover. In the case of the wheat there was practically the same effect from the rock phosphate, the acid phosphate and the complete commercial fertilizer. With the clover, however, the acid phosphate had a considerably greater effect, the rock phosphate showing a smaller influence and the complete commercial fertilizer the least beneficial effect. These results are of particular interest in that they indicate the possibility of value from the use of phosphorus fertilizers on the Clarion loam, the main soil type in this county. Just which material should be used on the type must be determined by more complete tests and particularly by field tests. It would seem from indications here that the differences in the relative value of the various phosphorus carriers may depend to a large extent upon the crop which is being grown.

It does not seem from these results that complete commercial fertilizers could be recommended as of any particular use on this soil.

Apparently the Clarion loam will respond to applications of farm manure and the use of lime in addition to manure is very desirable, especially when legumes are to be grown. The results indicate also that phosphorus fertilizers may be used to advantage on this soil and tests of the relative value of rock phosphate and acid phosphate are very desirable. Complete commercial fertilizers may also be tested but they seem to have less effect than the phosphorus carriers.

The results of the second greenhouse experiment on the Webster silt loam from Palo Alto county are given in table VIII.

Again with the Webster silt loam used in this experiment, the effect of manure, both on wheat and clover is quite evident. Both these crops were increased by the application of this material. Lime in addition to the manure had no effect on the wheat and only a very slight influence on the clover. This soil is

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TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER SILT LOAM, PALO ALTO COUNTY.

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	23.0	45.36
2	Manure	28.0	49.89
3	Manure+Lime	26.0	52.16
4	Manure+Lime+Rock phosphate	31.5	56.69
5	Manure+Lime+Acid phosphate	33.5	58.96
6	Manure+Lime+Complete commercial fertilizer	29.0	52.16

usually not acid, but in the case of this particular sample the surface soil was slightly acid and lime was applied, but the acidity was so slight that the lime had no effect.

The addition of phosphate fertilizers seemed to give increases both in wheat and clover, the acid phosphate showing up somewhat better in the case of both crops. The complete commercial fertilizer had little effect on either crop and, as on the Clarion loam, it showed very much less influence than did the rock phosphate and the acid phosphate.

It seems evident that on the Webster silt loam small applications of manure may bring about very profitable returns. In any case where the soil is acid, lime may be applied with profit and the indications point very strongly to the desirability of testing the use of phosphorus fertilizers on this type. Either acid phosphate or rock phosphate may be used in these tests, or preferably both materials may be applied to small areas and the comparative value of the two materials may then be determined. There is no evidence from these results of any particular value attached to the use of complete commercial fertilizer.

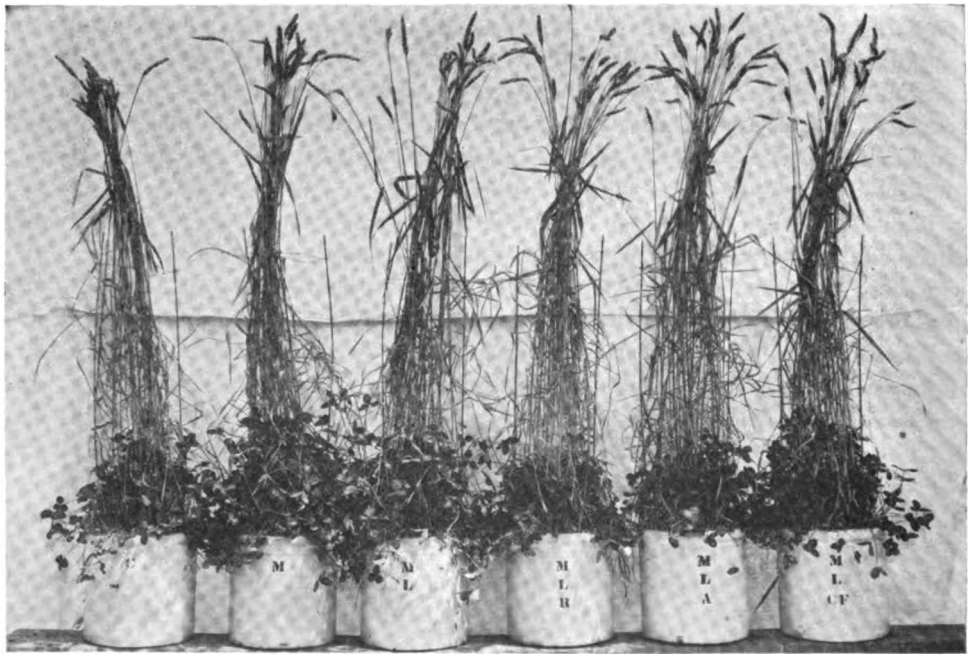

Fig. 4. Wheat and clover on Webster silt loam.

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Fig. 5. Clover on Webster silty clay loam.

Tests of phosphorus fertilizers, however, may include the use of these materials if the farmer is particularly interested, and in case field trials show profitable returns they may be employed.

The third greenhouse experiment was carried out on the Webster silty clay loam from Buena Vista county and the results are included here as they may be considered quite definitely indicative of the needs of this same soil type in Palo Alto county. The results of this experiment are given in table IX.

It is evident from the results in this table that the application of manure brought about a distinct increase in the yields, both of the wheat and the clover, the gains being more pronounced in the case of the latter crop. The addition of lime with manure increased the yield of wheat slightly and gave a very pronounced increase in the case of clover. Rock phosphate showed no effect on the wheat and very little on the clover. Acid phosphate brought about an increase in the wheat and a slight effect on the clover. The complete commercial fertilizer had practically no effect either on the wheat or clover.

Apparently manure is a most valuable fertilizing material for this particular soil type and this in spite of the fact that this soil is very well supplied with organic matter and nitrogen. The addition of lime along with manure is also apparently of value, particularly on the clover. There are indications that phosphorus fertilizers may be of value but no definite conclusions can be drawn from this particular experiment.

TABLE IX. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY.

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	26.56	29.5
2	Manure	29.46	36.0
3	Manure+Lime	31.71	44.0
4	Manure+Lime+Rock phosphate	28.95	46.0
5	Manure+Lime+Acid phosphate	35.80	45.0
6	Manure+Lime+Complete commercial fertilizer	31.13	46.0

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FIELD EXPERIMENTS

Several field experiments are just being started in Palo Alto county and these must be continued for several years before results from them will be available for use. However, experiments have been carried on for several years in Buena Vista, Clay and Webster counties on soil types which occur in Palo Alto county and the results from these field tests will undoubtedly indicate the results which will be secured in Palo Alto on the same soil types. The results of these field experiments are included in this report.

The field experiment at Lundgren in Webster county is on the Webster loam, an important type in Palo Alto county. The field at Everly in Clay county is on the O'Neill loam, a type of considerable interest in this county. Two series of experiments have been under way at Truesdale in Buena Vista county on the Carrington loam. The Clarion loam in Palo Alto county is very similar to the Carrington loam in Buena Vista, practically the only difference being somewhat more lime in the subsoil of the Clarion. Hence the results of the Carrington loam in Buena Vista may be considered to indicate the needs of the Clarion loam in Palo Alto county.

These field experiments are all laid out on land which is thoroly representative of individual soil types in the county. They are permanently located by the installation of corner stakes and it is planned to carry the experiments over a long period of years. Every precaution is taken in the application of fertilizers and in the harvesting of the crops to be certain that the results secured are accurate. While these fields are on a cooperative basis, the experimental handling of the plots is carried on by the Iowa Agricultural Experiment Station.

The plan of these tests is such that there are one or more series of plots on which various methods of soil treatment are used. One series includes the use of manure and therefore represents the livestock system of farming. A second series makes use of the crop residues, representing the grain system of farming, and no manure is applied. The results on the livestock series of plots only are given here inasmuch as the crop residue plots have not yet been conducted for a long enough time to show any effect of the residues.

Other fertilizing materials tested in these experiments are rock phosphate, acid phosphate, a complete commercial fertilizer and lime as needed. The rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is added at the rate of 200 pounds per acre annuallly and a standard 2-8-2 complete commercial fertilizer is used at the rate of 300 pounds per acre annually. Limestone is applied in a sufficient amount to neutralize the acidity of the soil and supply two tons additional.

There are 13 plots in these experiments, three of which are untreated or check plots and are numbered 1, 7 and 13. Plots 1 to 7 inclusive are included therefore in the livestock system and the results on these plots are the ones which will be considered in this report. The plots in these fields are all 1/10 of an acre in size being 156′ 6″ in length by 28′ in width.

THE EVERLY FIELD

The results obtained on the Everly field in Clay county are given in table X. This field is laid out on the O'Neill loam, a minor type in Palo Alto county but one which is of considerable interest because of its characteristics and the diffi-

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TABLE X. FIELD EXPERIMENT, O'NEILL LOAM, CLAY COUNTY.
Everly Field.

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover tons per acre 1921
1	Check	47.7	37.1	23.3	1.80
2	Manure	56.2	34.1	27.5	2.35
3	Manure+Lime	56.4	38.0	28.9	2.60
4	Manure+Lime+Rock phosphate	56.0	40.3	33.6	2.94
5	Manure+Lime+Acid phosphate	59.2	39.0	32.6	3.28
6	Manure+Lime+Complete commercial fertilizer	55.4	40.9	30.9	2.97
7	Check	46.6	37.1	24.1	1.80

culty which is sometimes experienced in securing satisfactory crops. The results secured on this field for 1918, 1919, 1920 and 1921 are given in the table. They are of particular interest inasmuch as the results of a complete four years' rotation are shown under the livestock system of farming and they indicate quite definitely the value of various fertilizing treatments on this particular soil.

The effect of the application of manure to this soil is quite definitely shown in these results. The yield on the check plot in 1919 is a little high and this prevents the effect of manure from showing that year. However, the yield of corn is very definitely increased in 1918, the oats in 1920, and the clover in 1921. The addition of lime along with manure showed a very slight effect on the corn and a somewhat larger influence on the oats and the effect on the clover was quite pronounced. This is what would be expected from the fact that lime exerts its beneficial effect particularly on the clover of the rotation and it is not expected that it will have any large influence on corn and oats. Applications of rock phosphate, acid phosphate and a complete commercial fertilizer quite generally increased the crops of the rotation. Acid phosphate showed up somewhat the best on the corn the first year and considerably better than the other materials on the clover in 1921. There is very little difference in the effect of the acid and rock on the oats in 1920, the rock giving a slightly larger effect. Similarly in 1919 the rock seemed somewhat superior to the acid.

The results of this test should not be considered, however, as definitely indicating the relative value of these materials. In most cases the differences are too small to be of great significance and further results are needed before definite conclusions can be drawn. It would seem evident, however, that phosphorus fertilizers will prove of value on this soil type and one material may be more valuable than another, depending upon the crop which is to be grown as well as upon the seasonal and soil conditions. Tests of the relative value of rock phosphate and acid phosphate are particularly desirable on individual farms in order that the material which will give the largest economic effects may be chosen. It is not a question merely of increased crop yields but one of cost of treatment in connection with increased crop growth. It is evident that this soil type should receive liberal applications of manure and that lime should be applied when needed for the best crop yields and the application of phosphorus fertilizers would probably be of value in most cases.

THE TRUESDALE FIELD

The results on the Truesdale field are given in table XI. This field is located in Buena Vista county on the Carrington loam which, as has been noted, is a

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TABLE XI. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY.
Truesdale Field—Series I.

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover tons per acre 1921
1	Check	38.9	56.5	57.2	1.40
2	Manure	44.3	57.1	57.9	1.20
3	Manure+Lime	46.4	58.1	59.2	1.60
4	Manure+Lime+Rock phosphate	54.4	58.7	64.7	2.45
5	Manure+Lime+Acid phosphate	49.6	58.7	64.9	3.30
6	Manure+Lime+Complete commercial fertilizer	49.6	58.7	64.7	3.10
7	Check	38.4	58.1	56.4	2.20

type very similar to the Clarion loam of Palo Alto county. The difference between these types involves chiefly the occurrence of lime in the subsoil and as this has little influence on the crop yields it may be concluded that the results on this field would apply directly to the Clarion loam in Palo Alto county.

In this experiment a complete four-year rotation has been carried out and the effects of treatment on two corn crops, one oats crop and one clover crop are shown.

Manure brought about a distinct influence on the corn in 1918 and a smaller effect on the same crop in 1919. A very little influence was noted on the oats in 1920 and none at all on the clover in 1921. In fact, the yield on the manure crop in 1921 was undoubtedly slightly abnormal in that a smaller yield was secured than on the check plot. The influence of lime along with manure is evident on all the crops of the rotation, showing up not only on the clover but on the corn and oats as well. It would seem that lime may exert a beneficial effect indirectly on the grain crops of the rotation and its value should therefore not be determined entirely by the effect on clover, altho that is the crop which is usually influenced to the largest extent.

The influence of rock phosphate, acid phosphate and a complete commercial fertilizer shows up quite distinctly on all the crops, altho the corn crop in 1919 is increased to only a small extent. The clover is increased to a much greater degree than the other crops in the rotation and with this crop the acid phosphate gives greater effects than the rock and the complete commercial fertilizer shows only a slightly smaller effect than the acid phosphate. On the oats the three materials give practically identical effects and similarly on the corn crop in 1919. On the 1918 corn crop, however, rock phosphate gave a larger yield than did the other materials. Apparently phosphorus may be of value on this particular soil type and the application of phosphorus fertilizers may lead to distinct crop increases. The results do not permit of conclusions regarding the relative merits of the various materials. Further experiments must be carried out before a definite choice can be made between acid phosphate and rock phosphate. The results seem to indicate, however, the superior value of acid phosphate on clover. The complete commercial fertilizer does not give any larger effects than the phosphorus carriers and in some instances the influence is less, hence it would seem that these materials would not prove as profitable as the phosphorus fertilizers owing to the fact that they are more expensive.

The results on Series II of the Truesdale field are given in table XII for the years 1920 and 1921. The yields of oats in 1918 were very irregular and the

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TABLE XII. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY.
Truesdale Field—Series II.

Plot No.	Treatment	Corn bu. per acre 1920	Corn bu. per acre 1921
1	Check	47.5	32.8
2	Manure	57.0	39.7
3	Manure+Lime	59.0	41.8
4	Manure+Lime+Rock phosphate	61.2	38.1
5	Manure+Lime+Acid phosphate	62.1	40.1
6	Manure+Lime+Complete commercial fertilizer	64.0	44.4
7	Check	57.1	36.2

clover in 1919 winter killed. Results on corn for 1920 and 1921, however, very largely confirm the conclusions reached in the discussion of the results of Series I. Here again the beneficial effect of manure is shown in increasing the corn yields. Lime in addition to manure gave a further increase. Rock phosphate, acid phosphate and a complete commercial fertilizer all increased the corn yields to a considerable extent with the exception of the rock phosphate in 1921 and on that particular plot the yield was evidently abnormal. It would seem from these results that a phosphorus fertilizer might be used on this soil with profit.

It is apparent from the results of these two experiments on the Truesdale field that manure is a particularly valuable fertilizing material for this soil and will exert a beneficial effect on all the crops of the rotation. Lime should be used when the surface soil is acid and the beneficial effect of this material will show up particularly well on the clover of the rotation. There is evidence that phosphorus fertilizers will prove of value on this soil and the testing of rock phosphate and acid phosphate on small areas is recommended. Complete commercial fertilizers do not seem to have any greater effect than the phosphorus carriers and hence they would prove less profitable owing to their greater cost. They may be used, however, provided comparative tests show them to be of superior value to the phosphorus carriers under any particular conditions.

THE LUNDGREN FIELD

The results of the experiment on the Lundgren field in Webster county are given in table XIII. The plots on this field are located on the Webster loam and the results secured on this particular type may be considered to indicate quite definitely the needs of the same soil in Palo Alto county. When this experiment was started the soil was not acid in reaction and no lime was applied, hence plots 2 and 3 are duplicates and the results given in the table are the averages of the yields on these two plots.

TABLE XIII. FIELD EXPERIMENT, WEBSTER LOAM, WEBSTER COUNTY.
Lundgren Field.

Plot No.	Treatment	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921
1	Check	59.0	63.8	32.9
2 }				
3 }	Manure	59.4	63.8	35.3
4	Manure+Rock phosphate	61.3	69.3	38.7
5	Manure+Acid photphate	65.1	67.2	35.8
6	Manure+Complete commercial fertilizer	65.1	74.2	36.6
7	Check	54.0	59.7	32.6

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The yield of oats in 1918 is not given in the table, inasmuch as the results are very irregular, as is apt to be the case during the first year of such an experiment. The effect of manure on this particular soil has not shown up very definitely altho the oats crop is increased to some extent.

Rock phosphate, acid phosphate and a complete commercial fertilizer all increased the crop yields to a considerable extent, the rock phosphate showing up better on the oats, the complete commercial fertilizer the best on the corn in 1920 and the acid phosphate and the complete commercial fertilizer both giving better effects than the rock on the corn in 1919. There is evidence here that phosphorus will be of value on this particular soil, but apparently many more results are needed before any definite conclusions can be drawn regarding the relative value of these two materials. The complete commercial fertilizers showed up better than the phosphorus carriers in one instance, but this should not be taken as conclusive, particularly in view of the fact that in 1921 it had less effect than the rock phosphate. Owing to its greater cost a complete commercial fertilizer must give very much larger yields if it is to prove economically profitable. It would not seem from these results that it would be as valuable a fertilizer for this soil as a phosphorus carrier. Small applications of manure are undoubtedly of use on this particular soil and for its continued fertility this material should be applied regularly in normal amounts. Phosphorus fertilizers should be tested and they will undoubtedly be needed in the near future if they are not of profit at the present time.

These field experiments as a whole very largely confirm the indications of the greenhouse tests and also the results of much farm experience. Apparently the soils of the county will very largely respond to applications of farm manure. Some of the types are in need of this material to a much greater extent than others, but in no case can the fertility be maintained without the proper application of farm manure, unless expensive commercial fertilizers are purchased as substitutes for it. Lime is of value on these soils when they are acid even tho the acidity is only slight and confined to the surface soil. Phosphorus fertilizers seem to be of value and either rock phosphate or acid phosphate may give profitable returns on general farm crops. Just which material should be used must be determined for individual soil conditions. Complete commercial fertilizers do not seem to prove any more valuable than phosphorus carriers and hence must be looked upon as less economically desirable.

THE NEEDS OF PALO ALTO COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The field experiments which have been begun in Palo Alto county have been planned to throw some light on the problem of the fertilizer needs of the more important soil types of the county. When results have been secured from these fields for a period of several years, it is hoped that economic conclusions may be drawn regarding the relative value of various fertilizers on these soils. At present field experimental results in this county are not available but from the results of the greenhouse tests given earlier in this report and from the results

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of certain field experiments in other counties, on soil types which are common to this county, certain suggestions may be given regarding the treatments needed for the soils of the county. Later it may be possible to draw more definite conclusions with respect to the use of certain fertilizers but it should be understood that the suggestions given here are based upon the laboratory, greenhouse and field tests which are discussed earlier in the report. They are also based upon the practical experience of many farmers and no recommendations are made which have not proven of value practically. In regard to the use of certain fertilizing materials, the suggestion is made that farmers test these materials on their own soils. If this suggestion is carried out they may secure very valuable and definite information pertaining to the use of fertilizers on their own soils and only in this way can it be definitely determined whether certain materials will prove of profit under the particular soil conditions. The suggestions which are made regarding definite soil treatments in this report are of proven value and may be put into operation under any farming conditions.

MANURING

The soils of Palo Alto county are very much better supplied with organic matter than is the case with the soils in many other counties. Only in one instance is the organic matter content extremely low and that is in the case of the Clarion fine sand, a very minor type in the county. In most instances the soils are fairly rich in organic matter. In the case of the more extensive upland types, however, the amount of organic matter is not at all excessive and in fact it is not so large but that care must be taken to keep up the supply.

The application of farm manure to many of these soils is of considerable value and it is probably the most valuable fertilizing material for use in the county. The experience of many farmers indicates that normal applications of manure to most of the upland types bring about increases in crop yields. The greenhouse and field experiments discussed earlier in this report show that manure will prove of value on these soils. This is the most economic material for keeping up the organic matter supply, and even where the content of organic matter is sufficient at present normal applications of manure should be made once in a rotation whenever the production of manure on the farm is sufficient. Even where other fertilizing materials are used on these soils, the greatest effects are secured when they are combined with applications of farm manure. There is no artificial material which can take the place of this natural fertilizer.

The beneficial effects of manure on soils are due to its influence on the chemical, physical and bacteriological conditions. The actual increase in plant food which it brings about may be of fundamental importance from the standpoint of crop yields and permanent fertility. Manure contains a large portion of the plant food constituents removed from soils by the crops grown and hence it returns considerable amounts of plant food which would otherwise be lost from the soil. Manure lengthens the life of the soil or in other words, it delays the time when one or more of the necessary plant food elements will become so low that crops will fail. It improves the physical condition of soils whether heavy or light. Heavy soils are opened up and made less retentive of moisture and better aerated. On the other hand, it makes light open soils less open and por-

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ous, more retentive of moisture and less subject to loss of valuable matter by leaching. The direct results of this improved physical condition in the soil is the greater development of roots and hence better growth of the plant, but the improved physical condition exerts a secondary effect on crops, in that bacterial activities are encouraged and there is a greater production of available plant food. Crops are, therefore, better supplied with necessary constituents.

Manure contains enormous numbers of bacteria and other microscopic organisms whose introduction into the soil may prove very beneficial from the standpoint of crop yields. This is due to the fact that bacteria are the agents bringing about the production of available plant food, and the introduction of larger numbers of these organisms may be responsible in a large part for the beneficial effect of manure on the yields of certain crops. The organic matter content of manure is very rich and this material plays a very important part in crop production and soil fertility. It also serves as a food material for bacteria and hence is one of the reasons for the greater production of available plant food. There are undoubtedly cases where the beneficial effects of manure are due chiefly to a stimulation of bacterial action either because of larger numbers of bacteria and other organisms or of better growing conditions. In newly drained reclaimed areas when manure brings about beneficial effects, as is so often the case, they are very apt to be due to improved bacterial conditions, especially if the area in question is as extremely high in organic matter as is usual in undrained soils. There are probably other cases where the beneficial effects of manure are due to the improved physical condition in the soil or to the actual addition of plant food constituents. In general, however, on the soils of this county it seems probable that manure is of value because of its chemical, physical and bacteriological effects, all combined.

The beneficial effects of manure when applied to soils are so important that every precaution should be taken to preserve the manure produced on the farm and see that it is applied to the soil without loss. On the average livestock farm a large part of the value of manure is lost by leaching and exposure to the weather. It has been estimated that 70 to 90 percent of the valuable matter in manure may disappear in this way. In cases where such large losses occur, manure will not exert its usual highly beneficial effects and crop yields will be lower. This means that the improper storage and utilization of manure will bring about actual money loss to the farmer. Every farmer, therefore, should take special care to preserve the manure produced on his farm without loss in order that he may obtain the best effects from its application. It may be stored in a covered yard or pit and protected from the weather or some particular method may be employed which is most desirable for the farm conditions. No one method can be recommended for all circumstances inasmuch as the conditions on farms are so variable. A very satisfactory method in one case might prove highly undesirable in another. Almost any method may be employed to prevent loss from manure, provided it is kept moist and compact and not exposed to the weather. Under some conditions the application of manure, as produced, to the soil may be very desirable. When this method of application is possible, of course no storage of the material is needed and hence it may be applied with the least possible loss of valuable portions, and with the largest

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effect on crop yields. It is not always practicable to apply manure as produced and in fact on most farms it is necessary to store the manure and apply at a convenient season.

When manure is properly stored and applied to the soil it is estimated under average livestock farming conditions that 75 to 80 percent of the plant food removed from the soil by the crops grown may be returned to the land. This estimate is based on the assumption that sufficient manure will be produced on the farm to make an application of 8 to 10 tons per acre to the entire acreage of the farm once in a four year rotation. There are many cases on livestock farms where this is not possible and then some of the soils of the farm are well supplied with manure while others receive it only very infrequently. The usual application of manure is 8 to 10 tons per acre for general farm crops, altho in some instances larger applications than this are made, particularly on light open soils or for the growth of garden or truck crops. It is not generally advisable, however, to apply more than 16 to 20 tons per acre under any soil conditions for general farm crops and larger applications should be made only in the case of special crops.

On many of the soils of this county it would be particularly undesirable to make unusually heavy applications of manure. In fact, where the soils are fairly well supplied with organic matter, care should be taken in applying the manure, as it may bring about undesirable effects, particularly on small grain crops. In the case of some of the soils of this county manure should be applied in the rotation as far away from the oats as possible in order that there may be no danger of lodging, which may occur when manure is applied immediately preceding the oats crop. The usual method is to make the application of manure to the first corn crop of the regular four year rotation and in this way no undesirable effects on the oats result.

On the grain farm where very little manure is available for use, some other source of organic matter and nitrogen must be utilized and on the average livestock farm it is quite generally impossible to keep up the nitrogen and organic matter by the use of manure alone. Under both systems of farming, therefore, there are instances where green manuring will prove a profitable practice as a supplement to or substitute for the use of farm manure.

Leguminous crops are by far the most desirable for use as green manures owing to the fact that when well inoculated they are able to utilize the free nitrogen of the atmosphere and hence when they are turned under in the soil they increase the amount of this constituent. They really act as a nitrogenous fertilizer, but they also supply large amounts of organic matter and hence may take the place, to a large extent, of farm manure. Non-legumes are sometimes used as green manures where the nitrogen content is not low and it is especially desirable to increase the organic supply. There are very few instances, however, under which non-legumes would be as satisfactory as legumes. There are so many legumes which may be grown and used as green manures that one may be chosen which will fit in with almost any rotation and with practically any soil condition.

Green manuring is not a practice which can be recommended for any extensive use in Palo Alto county, but there are undoubtedly conditions under which

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the turning under of a leguminous crop or at least a portion of a leguminous crop will aid materially in keeping up the organic matter and nitrogen in the soil. Even the plowing under of a part of the clover crop of the regular rotation is somewhat of a green manuring practice and often proves of value under grain farming and some livestock farming conditions. Green manuring should never be practiced carelessly nor blindly, as it may bring about undesirable effects if not carried out properly. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The organic matter content of soils may also be kept up to a considerable extent by the proper utilization of crop residues. If such materials as straw and stover are burned or otherwise destroyed there is an actual loss of a valuable natural fertilizing material. Many farmers by following such practices actually waste a very important means of keeping their soils productive. Such materials should be used for feed or bedding on the livestock farm and returned to the soil along with the manure. On the grain farm they may be applied directly to the soil or they may be stored and allowed to decompose partially before application. Under the latter system of farming it is particularly important to utilize the residues, inasmuch as manure production is so small. Not only do crop residues supply organic matter to the soils, but they contain considerable amounts of plant food constituents and thus they may have an important effect in lengthening the life of the soil. The value of crop residues in increasing crop yields and keeping soils productive is such that they should be considered as valuable supplements to manure and green manures for maintaining the soil in the best condition for crop growth.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Palo Alto county are not extremely low in phosphorus supply, but neither is there any large amount present and it may safely be concluded that phosphorus fertilizers will be needed on these soils in the near future. Furthermore, it is quite possible that these materials may prove of value in some cases at the present time. The supply of available phosphorus may be insufficient to produce maximum crops, even altho the total phosphorus content is apparently quite adequate. There is no way to determine the amount of available phosphorus in these soils with any degree of accuracy except by making applications of phosphorus fertilizer to a small area. The analyses of the soils merely indicate the total supply and it remains for actual tests to show how fast this supply is being made available for plant use. It may be calculated that there is sufficient phosphorus to supply crops for a good many years but in spite of this rather considerable total content applications of phosphorus fertilizers may give crop increases. The greenhouse and field experiments described earlier in this report indicate that this may actually be the condition in some of the soils of Palo Alto county. Phosphorus fertilizers may yield profitable increases in crops at the present time. Field tests with these materials are under way and will permit of definite conclusions after several years' results have been secured. For the present it can only be urged that farmers test the value of phosphorus on their own soils.

If phosphorus fertilizers prove profitable, the next question which arises is which particular fertilizer should be used. Acid phosphate and rock phosphate

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are the two common sources of phosphorus and considerable interest has centered around the selection of one of these materials. Acid phosphate is a commercial manufactured fertilizer in which the phosphorus is available and ready for plant use. Rock phosphate is a natural product and the phosphorus contained in it must be acted upon by certain agencies before it is of use to crops. Acid phosphate costs considerably more than rock phosphate but the latter material must be applied in very much larger amounts. Acid phosphate is applied annually in the spring while rock phosphate should be applied in the fall and in the regular four year rotation is usually plowed under with clover. If manure is applied to the soil and the general conditions in the soil are satisfactory, the phosphorus in rock phosphate may be changed to an available form very rapidly.

The experiments which are now under way in Palo Alto county are testing the value of these two phosphorus carriers and when definite results are secured the choice of the material to be used will depend upon the cost of the application and the value of the crop increase, taking into account the use of rock phosphate only once in four years and the application of acid phosphate annually. Farmers may test the use of these two materials on a small scale on their own farms and determine quite readily which material should be used. Directions which may be followed in carrying out simple tests with the use of these fertilizers are given in circular 51 of the Iowa Agricultural Experiment Station and farmers who are interested in carrying out such tests may secure further advice and information if they will write to the Soils Section.

The nitrogen content of the soils of Palo Alto county is extremely variable but in most cases the soils are very well supplied. It should not be assumed, however, that the amount present is sufficient so that crops may be grown indefinitely and nitrogen removed continually without reducing the fertility of the soil. Nitrogen may disappear very rapidly from soils by the removal of crops and by the washing away of soluble nitrates in the drainage water. Hence it is very important that the nitrogen content of soils be kept up thru the use at regular intervals of some nitrogenous fertilizing material. Farm manure and crop residues reduce the loss of nitrogen from soils when they are properly utilized and very often some other nitrogenous fertilizer must be employed to increase the nitrogen in the soil. When this is true, leguminous green manures should be used. They are the cheapest and most satisfactory nitrogenous fertilizers. Commercial nitrogenous fertilizers cannot be recommended for general farm crops. They may be of value in some instances as top dressings or for the growth of special crops but there is probably no case in which they should be used in this county. Legumes when well inoculated take their nitrogen from the air and hence when a portion or all of a legume crop is turned under in the soil there may be an increase in its nitrogen content. If a legume is used in a rotation under any system of farming, and every satisfactory rotation should contain a legume, there should be some addition of nitrogen to the soil. If the legume is used for hay then the nitrogen in it which was obtained from the atmosphere will be returned in large part in the manure. If a portion of the crop is turned under in the soil there will be an increase in nitrogen corresponding to the size of the crop. If only the seed of the crop is removed, there may be a

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very large gain in nitrogen thru its growth. The proper selection and utilization of legumes is the solution of the nitrogen problem and permanent fertility and for the soils of this county the nitrogen content may be kept up thru the proper growing and handling of the legume crops of the rotation.

Analyses of a large number of soils of the state have shown that potassium is present in large amounts in practically all cases and it is very unlikely therefore that potassium will be needed on the soils of Palo Alto county for many years to come. If desirable physical conditions are maintained in the soil, the production of available potassium will be entirely adequate to keep crops supplied almost indefinitely. The proper drainage of the soils is a very important factor in insuring the satisfactory production of available potassium. The proper aeration of the soil which is accomplished by drainage and the use of farm manure and lime is the second factor of significance. The addition of organic matter to the soils is a third factor which should be taken into account. When drainage, aeration and organic matter supply are adequate, bacterial activities are increased and the production of available potassium will proceed rapidly. There may be instances where a potassium fertilizer would bring about some crop increase but this is very unlikely to be the case anywhere in Palo Alto county. If such materials are tested on a small scale, however, and show economic value, they may be utilized on larger areas without injury to the soil.

Complete commercial fertilizers cannot be recommended at the present time for use in this county. Nitrogen may be supplied by legumes and potassium is present in such large amounts that it seems very unlikely that complete fertilizers containing these two elements along with phosphorus would prove as economically desirable as phosphorus carriers. However, the field tests in the county include the use of a complete fertilizer and definite results will be obtained later which will show how such materials compare with acid phosphate and rock phosphate. Farmers may test these materials on their own soils if they are interested, making an application to a small area and comparing the effects on crop yields with those secured from the use of acid phosphate. If the complete fertilizers show more profit than the phosphorus fertilizer then the former may be used without fear of injury to the soil. They are not recommended for general use but there is absolutely no objection to their use if profitable returns are secured.

LIMING

Many of the soils of Palo Alto county are basic in reaction and not in need of lime. The Clarion loam, however, the most extensive soil type in the county, is slightly acid in the surface soil and the same condition exists in the Clarion fine sand. The two O'Neill soils on the terraces are likewise acid in reaction and the Webster loam and the Cass loam show almost a neutral reaction. In practically all these cases with the exception of the two O'Neill soils, the lower soil layers are well supplied with lime. This, however, does not mean that lime should not be applied to these soils when they are acid at the surface. Lime rarely moves upward in the soil and the amount present in the lower soil layers has very little influence on the surface soil. It is very necessary that the surface soil of the main upland types in the county be tested for acidity or lime require-

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ment and if the most satisfactory crops are to be secured, particularly of legumes, the amount of lime shown to be necessary according to the tests should be applied.

There is a continual removal of lime from the soil by utilization by crops and by leaching and even altho the soil may not show acidity at the present time, the need of lime may become evident in the future, hence tests for acidity should be made at regular intervals, at least once in the ordinary four year rotation.

The figures given in the tables should be considered to indicate merely that the soils which are acid in this county require only comparatively small amounts of lime. Applications of lime to these soils should be made only after tests have been made on the individual soils. The acidity in soils is so extremely variable that even average figures of many tests will not show the needs under any one particular soil condition.

These Palo Alto county soils which show an acidity according to the tables and including the Clarion loam, the Webster loam, the Clarion fine sand, the O'Neill fine sandy loam and the O'Neill loam, should all be tested at regular intervals for acidity and lime should be applied as needed if the best yields of crops are to be secured, particularly of legumes such as clover and alfalfa. Farmers may test their own soils and determine the lime requirement but it will be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they will be able to apply the proper amount of lime and avoid the use of an insufficient amount or an excessive application. One test for soil needs should not be considered sufficient but the soils should be tested at regular intervals and the supply of lime kept up thru regular applications.

The beneficial effects of lime on soils have been shown by many experiments and much field experience. Legumes are very largely benefited by this material but in many cases other crops are increased to a considerable extent also. The experiments which have been discussed earlier in this report show some beneficial effects from lime on the various crops of the rotation and while, therefore, this material is needed to a much less extent in Palo Alto county than in many other sections of the state, whenever the soils are acid, lime should be applied and must be applied if the best crop growth is to be secured and the soils of the county are to be kept in a high state of productivity.

DRAINAGE

Drainage is probably one of the most important treatments needed for many of the soils of Palo Alto county. The fact that there are large areas of inadequately drained land has been mentioned earlier. The drainage map given in this report shows very definitely that there are considerable areas of gently undulating to flat land from which the excess moisture is not removed sufficiently rapidly. Under such soil conditions crop growth is not satisfactory and in fact in some seasons crops may fail completely. The upland soils of the Webster series are characterized by a level topography and particularly in the case of the Webster silty clay loam the drainage is very poor. The Clarion loam is ordinarily fairly well drained but the Webster loam and the Webster silt loam

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are quite generally in need of tiling especially where the areas are flat. The bottomland types of the Lamoure and Wabash series are in need of drainage as are also the areas of peat and muck. The Rogers silt loam is also in need of drainage. In fact the only types in the county which are really entirely adequately drained are the O'Neill types and the Clarion fine sand. In many instances tiling is very necessary to bring about satisfactory crop production on these soils. In some instances ditching may be needed in order to provide outlets for the tile.

Considerable drainage work has been done in the county and large areas of land have been rendered highly productive. There is considerable evidence, therefore, that the expense of drainage even tho considerable is well warranted when the value of the crops grown is taken into account. No other treatment will take the place of drainage and other treatments will not bring about satisfactory effects if drainage conditions are unsatisfactory. In general it should be emphasized that the first treatment needed by many of the soils of Palo Alto county is adequate drainage and when this is true, tiling out of these areas should be done if satisfactory crop yields are to be secured.

THE ROTATION OF CROPS

The natural fertility of all soils is very rapidly reduced by the continuous growing of any one crop. From year to year there is a gradual removal of fertility and this is accompanied by a gradual decrease in the value of the land. The result, therefore, is to decrease the income of the farm and to reduce its value. A proper rotation of crops will prevent this reduction in fertility to a very large extent. Occasionally a particularly profitable crop is grown continuously and it is believed that the practice is of monetary advantage to the farmer. Such, however, is not the case. Experiments have shown that the rotation of crops actually brings in more money to the farmer than the continuous growing of any one crop. This is due to the fact that the crop yields are reduced so rapidly under continuous cropping. No particular experiments were carried out with crop rotations in Palo Alto county, but the following rotations may be given, as they are common in the state and have generally given very satisfactory results. Various modifications of these rotations are practiced and almost any rotation may be employed provided it contains a legume and the most profitable crops.

1—FOUR OR FIVE-YEAR ROTATION

First year: Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
Second year: Corn.
Third year: Oats (with clover or with clover and timothy).
Fourth Year: Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy).

2—FOUR-YEAR ROTATION WITH ALFALFA

First year: Corn.
Second year: Oats.
Third year: Clover.
Fourth year: Wheat.
Fifth year: Alfalfa. (This crop may remain on the land five years, and the fields should then be used for the four-year rotation outlined above).

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3—THREE-YEAR ROTATION

First year: Corn.
Second year: Oats or wheat (with clover seeded in the grain).
Third year: Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land to be returned to the soil).

INDIVIDUAL SOIL TYPES IN PALO ALTO COUNTY*

There are thirteen individual soil types in Palo Alto county and these together with the gravelly subsoil phase of the Clarion loam and an area of peat and muck make a total of fifteen separate soil areas. They are divided into three large groups according to their origin and location and these groups are known as drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are seven drift soils in the county and one phase, making a total of eight drift soil areas. They are classified in the Clarion, Webster and Rogers series and together they cover a total of 70.6 percent of the area of the county.

CLARION LOAM (138)

The Clarion loam is the most extensive individual soil type in the county as well as the largest drift soil. Together with the gravelly subsoil phase, which is very minor in extent, it covers 37.7 percent of the total area of the county.

It occurs in typical areas in all parts of the county occupying about one-half of the total upland area in the southwest quarter of the county. In the area northeast of the West Fork Des Moines river it occurs in relatively small areas on the uplands which are typically covered with the Webster series.

The surface soil of the Clarion loam is a brown to dark brown mellow loam 16 to 20 inches in depth. The subsoil is a grayish-brown to grayish-yellow heavy fine sandy loam to clay loam. In the lower subsoil there are frequently faint gray mottlings or a solid gray color. Near Fairville and Depew, as well as in the vicinity of Lost Island and Virgin Lakes, the surface soil has lighter color and may approach a very fine sandy loam in texture. In the western townships which are in the morainic area, the surface soil is a lighter brown to brown loam, 12 to 18 inches deep, underlaid by a friable clay loam to fine sandy clay loam. Boulders, stones and gravel frequently occur on the surface and thruout the three foot section. In the northwestern part of the county where the topography is more rolling, the surface soil is shallower and the gray glacial till appears within the three foot section. Nearly everywhere thruout the type the lower subsoil shows a sufficient lime content to effervesce with acid. There are included within this type very small areas of the Clarion fine sandy loam and the gravelly subsoil phase of the Clarion loam which are too small to separate on the map.

In topography this soil is generally undulating to rolling. In the northwestern part of the county along the Emmet county line, the topography is strongly

*The description of individual soil types given in this report very closely follow those given in the Bureau of Soils report.

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rolling. Likewise near streams and lakes there are some strongly rolling areas. Practically all of the Clarion loam is well drained and is not in need of tiling.

This soil is typically a prairie soil and the forested areas are confined to a few narrow belts of maple, willow, ash, walnut, cottonwood and oak along the river and to areas which have been planted for windbreaks. Practically all of the type is in cultivation or pasture. Corn, oats and hay are the most important crops grown. Corn is grown most extensively and yields on the average 35 to 60 bushels per acre. Some of the crop grown is sold but the major portion is used for feeding hogs, cattle and work stock. Oats are grown to a considerable extent with average yields of 35 to 60 bushels and much of this crop is used for feeding purposes, only a comparatively small portion being sold out of the county. Barley, rye, wheat, millet, sorghum, apples and all kinds of garden truck are grown by most of the farmers chiefly for home use. A small amount of the barley and rye and all of the wheat is sold and shipped out of the county. Rape is frequently seeded in the corn and used for feeding in the hogging down process. Alfalfa is grown occasionally but the chief hay crop consists of clover and timothy. Average yields of hay amount to 1½ tons per acre and the crop is practically all utilized for feeding purposes.

The Clarion loam is naturally a rather rich productive soil but increased crop yields may be secured and the soil kept more highly productive if proper methods of treatment are followed. The supply of organic matter is not extremely high and applications of farm manure would be of value in most cases. If farm manure is not available, then the leguminous crop in the rotation should be utilized, at least in part, as a green manure, and in some instances it would undoubtedly be desirable to make use of the entire crop in this way. The nitrogen content may be increased thru the use of a legume and it is very necessary that some means be taken to increase and maintain the nitrogen supply in the soil. The surface soil of the Clarion loam is usually acid in reaction and altho in most cases the lower soil layers are well supplied with lime, if the surface soil is acid the amount of lime shown to be necessary according to the test should be applied. It is very advisable that this soil be tested for lime requirement at regular intervals if it is to be kept in the best reaction for the growth of crops and particularly of legumes. The amount of phosphorus present in the soil is not very large and it would seem that applications of phosphorus fertilizers might be of value at the present time. They will undoubtedly be needed in the near future inasmuch as the total supply is decreasing and there is little possibility of the required available phosphorus being produced sufficiently rapidly in all cases. The field experiments which are located on this type have not yet yielded results and hence definite recommendations regarding the use of phosphorus and also regarding the particular phosphorus fertilizer which should be used, cannot be given. It is urged, however, that every farmer who is interested test the value of acid phosphate and rock phosphate on his own soil and thus determine for his own conditions the need and value of this material. Later the results of the field experiments will be available and more definite recommendations can undoubtedly be made. There is probably no need of applications of complete commercial fertilizers to this soil type and hence these materials are not recommended for use at the present time. If tests on a

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small area show them to be of value, they may be used, however, without fear of injury to the soil. Nitrogen may be supplied in considerable amounts by the growth of inoculated legumes and potassium is present in practically all cases in very large amounts. It would seem quite certain that phosphorus fertilizers would prove quite as valuable as the more expensive complete brands.

CLARION LOAM (Gravelly Subsoil Phase) (147)

This is a very minor type in the county, covering less than one percent of the total area. It occurs in small disconnected areas on the crests of ridges mainly in the northwest part of the county where the more rolling to rough areas of the upland are found. Several areas are found in Highland township and in Lost Island township and there are areas south of Graettinger and west of the river in Walnut township. There are a few small areas east of the West Fork Des Moines river and a few in the southern part of the county, especially in the vicinity of Rush Lake.

The surface soil of this phase is a light brown to brown light textured loam 7 to 9 inches in depth. The subsoil is a pale yellow to brownish-yellow fine sandy loam to fine sandy clay loam, faintly mottled with gray. Gravel appears thruout the subsoil and on the tops of the hills in the rougher areas the glacial till often appears in the three foot section. In topography the soil varies from rolling to strongly rolling and the drainage is good to excessive.

The larger part of this soil is utilized for pasture and only the areas on the more even slopes and rounded hills can be cultivated. It makes a good pasture soil and in the rougher portions it is probably most satisfactory when used in this way. When farmed along with the typical Clarion loam lower yields are secured. This is the only type in the county which is subject to erosion but when cultivated in the rougher areas there may be considerable washing. This would indicate the desirability of keeping such areas in pasture or in uncultivated crops. Contour plowing should also be practiced in order to prevent washing and probably in most cases cover crops should be grown. Other treatments which are needed when this soil is cultivated to make it more productive are the application of manure, or the turning under of leguminous crops as green manures. The use of phosphorus might prove of value and when the surface soil is acid lime should be applied.

WEBSTER LOAM (55)

The Webster loam is the second largest soil area in the county covering 28.0 percent of the total area of the county. It is found mainly in the northeastern part of the county and is the chief upland type in the entire area east of the West Fork Des Moines river. There are, however, many other areas of the Webster loam south and west of the river, occurring on the uplands in connection with the Clarion loam. This type is of particular importance in Ellington, Rush Lake and Great Oak townships.

The surface soil of the Webster loam is a very dark brown to black heavy loam 15 to 18 inches in depth. The subsoil is a grayish-brown to drab silty clay mottled with gray, yellow and brown. In some areas there is a subsurface layer between 18 and 22 inches which consists of a dark brown to almost black heavy loam to silty clay loam. There are small bodies of Webster silt loam and silty

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clay loam which are included with this type as they are too small to be shown separately on the map. In the more level portions the surface soil is somewhat higher in clay and more sticky when wet.

In topography the Webster loam is very gently undulating to gently rolling. The more level topography and heavy subsoil have brought about poor drainage conditions and this type is very frequently in need of tiling in order to permit of satisfactory crop growth. Usually when adequate drainage is accomplished crop yields are very satisfactory.

Practically all of this soil is devoted to the growth of crops. Corn, oats, and hay are the chief crops grown and of these corn is by far the most important. It yields 35 to 40 bushels per acre on the average while under favorable seasonal conditions, yields of 80 to 90 bushels are secured. Much of the corn produced is utilized on the farms for feeding. Some of it is used for ensilage. The surplus is sold to the local elevators. Oats yield 35 to 50 bushels per acre and are largely used for feeding stock on the farms. The hay crop consists principally of clover or clover and timothy mixed and yields of 1 to 1½ tons per acre are secured. The entire crop of hay is utilized for feeding purposes. Small areas are utilized for growing wheat, rye, flax, barley, millet, sorghum and rape. The wheat and flax grown are all sold out of the county. Rye is used principally for spring pasturage, while barley, millet, and rape are used entirely in this way. Some of the sorghum produced is used for making syrup.

The Webster loam is a rather productive soil but crop yields may be increased thru proper treatments. It will respond to small applications of farm manure and this material or leguminous green manures should be used to keep up its content of nitrogen and organic matter. If it is acid in the surface soil as occasionally happens, applications of lime should be made. Ordinarily, however, it is not in need of lime. Phosphorus fertilizers may prove of value in certain cases and tests of rock phosphate and acid phosphate on the type are very desirable. The chief need of this soil is for more adequate drainage. In the more level areas particularly, the installation of tile is a very important operation and very necessary if the yields of all crops are to be satisfactory. This is particularly true of course in seasons of high rainfall. After the tiling of these areas has been accomplished it is often very desirable to make a small application of farm manure to stimulate the production of available plant food and insure the satisfactory feeding of the future crop.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is a minor type in the county covering 2.8 percent of the total area. Like the Webster silt loam it occurs mainly in the northeastern part of the county in the area just east of the West Fork Des Moines river. There are small scattered areas of the type, however, thruout the portion of the county east of the river and a few areas are found west of the river in the southern part of the county. It occurs in comparatively small disconnected borders on the flatter sections of the uplands or on the slopes to the drainageways. It is found chiefly in association with the Webster loam of the upland.

The surface soil of this type is a very dark brown to black silty clay loam 14 to 16 inches deep. The subsoil is a yellowish-brown, drab or yellow tenacious

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silty clay loam to silty clay mottled with gray and yellow. Boulders appear thruout the type both in the surface soil and subsoil.

In topography it varies from undulating to gently sloping and natural drainage is deficient. Probably 85 percent of the Webster silty clay loam is in cultivation. The undrained areas are left in native grasses which are either pastured or cut for hay. The only trees growing on this type are a few willows. Corn is the most important crop grown on the cultivated portion of the type and yields from 35 to 60 bushels per acre on well drained areas. Oats is a second crop of importance yielding from 40 to 50 bushels per acre. Iowa 105 and Iowa 103 are most desirable for use on this type as they are less apt to lodge. A large part of the corn produced and practically all of the oats is used for feed on the farm. Flax, which is occasionally grown on sod ground, produces from 8 to 12 bushels per acre. Wheat, barley and rye are grown to some extent.

The Webster silty clay loam is chiefly in need of drainage in order to make it more productive. When this is accomplished yields of general farm crops are quite satisfactory. Small applications of farm manure would be of value on newly reclaimed land and this material should be utilized regularly to keep up the organic matter supply. Applications of phosphorus fertilizers might be of value in some cases and tests of rock phosphate and acid phosphate are very desirable. This soil is basic in reaction at the present time and probably will not be in need of lime for years to come. Drainage is a factor of chief importance here and large crop yields are frequently secured on otherwise unproductive areas by the mere installation of a line of tile.

WEBSTER SILT LOAM (113)

The Webster silt loam is a minor type in the county covering 1.7 percent of the total area. It occurs mainly in small disconnected areas scattered thruout the Webster upland in the eastern part of the county and in the southern part of the county south and west of the West Fork Des Moines river. The largest area is west of Cylinder along the county line. There are only a very few almost insignificant areas west of the river.

The surface soil is a black heavy silt loam 8 to 12 inches in depth. The subsoil is a black silty clay loam to silty clay which grades at 22 to 24 inches into a mottled yellow, grey and brown plastic silty clay. It is typically high in content of lime and numerous iron stains occur thruout the soil. In many cases the surface material for a depth of 1 to 2 inches consists of a black fibrous muck which indicates a relatively high content of organic matter and explains the analyses given earlier in this report which showed an unusually high content of organic carbon and nitrogen in this particular type. This mucky surface condition is peculiar to the Webster silt loam in this county and hence the analyses are not representative of the same type in other counties. Boulders occur thruout the soil and subsoil. In topography the Webster silt loam is flat to gently sloping and the natural drainage of the soil is poor.

Only the few small areas of the type where artificial drainage has been installed are in cultivation. In these areas corn and oats are the principal crops grown, corn yielding 30 to 40 bushels per acre and oats 35 to 45 bushels. There are small acreages also in barley, flax and rye. The larger part of the type is

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uncultivated and grows chiefly wild grasses most of which are cut for hay which is used for feed on the farms.

The Webster silt loam is a particularly rich productive soil when drained but satisfactory cultivated crops cannot be grown until thoro drainage is established. It is high in organic matter and nitrogen and abundantly supplied with lime, hence additions of organic materials and lime are not necessary at the present time except that small applications of farm manure would be of value on newly drained areas in stimulating decomposition and the production of available plant food. The phosphorus content is not particularly high and phosphorus fertilizers might be of value on this type when cultivated crops are grown.

CLARION FINE SAND (148)

This is a very minor type in the county, covering 0.2 percent of the total area. It occurs in narrow strips along the West Fork Des Moines river separating the uplands from the river-bottoms. The largest area extends from near Osgood in a narrow strip south for almost three miles. There are other very much smaller areas of the type occurring in similar positions along the edge of the uplands bordering the West Fork Des Moines river.

The surface soil of the Clarion fine sand is a light brown to grayish-brown fine sand 18 to 20 inches in depth and underlaid by a yellow loose textured fine sand. The topography of the type is gently undulating to rolling and the areas are 20 to 30 feet above the level of the river flood plains. Drainage is very satisfactory.

All of the type is under cultivation, the principal crops grown being corn, oats, wheat and clover. The yields of these crops are slightly less on the average than those secured on the Clarion loam. This soil is chiefly in need of organic matter in order to make it more productive and should receive liberal applications of farm manure and in many cases leguminous green manures would undoubtedly prove of value. It is acid in reaction in the surface and applications of lime should be made as shown to be necessary by tests. The phosphorus supply is not high and applications would probably prove of value for general farm crops. It should be emphasized, however, that the use of farm manure and the turning under of leguminous green manures to supplement the former, are practices of particular significance on this type.

ROGERS SILT LOAM (140)

The Rogers silt loam is a very minor type in the county, covering only 0.1 percent of the total area. It occurs in the beds of former shallow lakes which have been drained and only two areas are mapped in this county, one just south of Ruthven and the other south of Mallard.

The surface soil of this type is a grayish-brown to gray silt loam 18 to 20 inches deep, smooth and velvety when wet and having a floury structure when thoroly dry. The subsoil is a greenish-brown to brownish-gray silt loam. There is a very high content of lime thruout the soil both surface and subsoil. In topography it is practically level and drainage is inadequate. About one-half of the type has been brought under cultivation, the remainder supporting a growth of water-loving grasses which are used for hay.

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The chief need of this type to make it more productive is thoro drainage and cultivation and with these treatments satisfactory yields of most crops should be secured. Probably a small application of farm manure would aid when the land is newly tiled out. Eventually phosphorus fertilizers will prove of value when cultivated crops are being grown but for the present the only recommendation for the soil is adequate drainage.

CLARION FINE SANDY LOAM (149)

The Clarion fine sandy loam is of very minor importance in the county covering only 0.1 percent of the total area. It occurs only in small areas in the western part of the county along the Clay county line. Toward the east the type changes in texture and merges into the Clarion loam. The soil is developed to a considerable extent in Clay county and the areas in Palo Alto county are continuations of those found in Clay. Several areas of this type are included with the loam because of their small extent.

The surface soil of this type is a dark brown sandy loam extending to a depth of 8 to 10 inches. This rests upon a grayish-brown rather compact fine sandy loam which below 24 inches grades into a light brown fine sand or a grayish-yellow silt loam very much like the subsoil of the Clarion loam. If the lower subsoil is very sandy it may not show a high lime content. In general, however, there is a large amount of this material in the lower layers of this type.

This soil occurs on low ridges and hills and the drainage is entirely adequate. About 80 percent is cultivated, the remainder being in pasture. The same crops are grown as in the case of the Clarion loam and the yields secured are very much the same. The soil is acid at the surface and in need of lime especially for the growth of legumes. It will respond to applications of farm manure and if this materail is not available leguminous green manures should be used in order to build up the supply of organic matter and nitrogen. It would probably also respond to applications of phosphorus fertilizers. The general treatments recommended for the Clarion loam would apply to the Clarion fine sandy loam.

TERRACE SOILS

There are two terrace types in the county, both belonging in the O'Neill series. Together they cover only a small proportion of the total area, 3.3 percent.

O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is comparatively small in area in the county covering but 1.7 percent of the total area. It occurs in several areas along the West Fork Des Moines river, the largest being found near Graettinger, Osgood and Emmetsburg. In the southern part of the county the type occurs in numerous small areas. It is found on the terraces 15 or 20 feet above overflow.

The surface soil consists of 12 to 16 inches of brown to dark brown loamy fine sand or fine sandy loam. The subsoil is a light brown to a yellowish-brown loose textured fine sandy loam passing into layers of sand and gravel below 20 to 26 inches. In some areas the surface soil grades directly into a light brown to yellowish-brown loamy sand which in turn passes into the sand and gravel at about 24 inches. A few areas of the O'Neill loam too small to show on the

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map are included within this type. In topography it is level to gently sloping, drainage is excessive and crops are apt to suffer from drouth.

About 80 percent of the type is in cultivation, the remainder being used for pasture which is largely made up of wild grasses. Corn is the chief crop grown and oats is second in acreage. Some rye is produced. Corn yields 20 to 25 bushels per acre, oats 30 to 42, and rye 22 to 37 bushels. A small amount of popcorn is grown on this type also.

The chief need of this soil to make it more productive is the incorporation of organic matter. Liberal applications of farm manure are very desirable and where this material is not available in sufficient amounts leguminous green manure crops should be employed. Building up the soil in this material makes it less drouthy and hence insures better crop production. The nitrogen content may also be kept up in this way. Phosphorus fertilizers would probably prove of value in some cases now and certainly will be needed in the near future.

O'NEILL LOAM (108)

The O'Neill loam is very similar in size to the fine sandy loam, covering 1.6 percent of the total area of the county. It occurs in numerous areas on the terraces of the West Fork Des Moines river and along Cylinder, Pilot and Beaver creeks. The largest area is along Cylinder creek, extending north for four miles from Cylinder. The second largest area is directly west of Emmetsburg. The remaining areas of the type are rather small and of minor importance.

The surface soil of this type is a dark brown to chocolate brown light textured loam 8 to 10 inches in depth. The subsoil is a reddish-brown to yellowish-brown sandy loam grading at 18 to 24 inches into a layer of yellow sand or sand and gravel. There are a few areas of the fine sandy loam included in this type as they are too small to show separately on the map. The topography of this soil is slightly sloping and it occurs 2 to 5 feet above the adjacent bottomland. The drainage of the type is adequate to excessive and crops may suffer for moisture in dry seasons.

About 95 percent of this soil is under cultivation. The principal crops grown are corn and oats. In favorable seasons corn yields 20 to 40 bushels per

Fig. 6. A typical Palo Alto county farmstead. Lamoure silty clay loam in foreground.

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acre and oats 30 to 40 bushels. In dry seasons these crops may fail almost completely. Wheat, rye, millet, sorghum, popcorn and potatoes are produced on a small scale, chiefly for home use.

This soil is particularly in need of organic matter in order to make it more productive and to reduce the injurious action of dry seasons. Liberal applications of farm manure are very necessary or leguminous crops should be used as green manures in order to build the soil up in nitrogen and organic matter. It is acid in reaction and should be limed. The phosphorus supply is low and additions of phosphorus fertilizers might prove of value at the present time and will undoubtedly be needed in the near future.

SWAMP AND BOTTOMLAND SOILS

There are four swamp and bottomland types in the county and one area of peat and muck, making five soil areas. These are classed in the Lamoure, Wabash, and Cass series and the areas of peat and muck are not separated, but are mapped under the combined name. The combined area of swamp and bottomland soils in the county amounts to 26.1 percent of the total area.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is the most extensive bottomland type in the county and it is the third largest soil type, covering 14.4 percent of the total area. It is developed in many small areas in all parts of the county along the main streams, the tributaries and the intermittent drainageways. It is usually found in narrow areas following the course of the streams and drainageways, altho in many instances it occurs in depressed areas in the upland where drainage is deficient or actually lacking. The largest single areas of this type are one mile east of Medium Lake and east of Cylinder. There is also a rather extensive continuous irregularly shaped area east of Curlew and extending north and south along Beaver creek and some of the intermittent drainageways which join this creek. The greater portion of the type, however, is found in very small strips or disconnected areas.

The surface soil of the Lamoure silty clay loam is a black silty clay loam to heavy silt loam extending 12 to 16 inches in depth. The subsoil is a yellowish-brown, drab or mottled gray, yellow and brown silty clay loam showing iron stains at the lower depths in many areas. The subsoil is usually high in lime content and occasionally the surface soil is also well supplied. In some areas the lime content is very low or lacking in the surface soil and even the subsoil may give only a faint indication of lime. Within this type there are many minute areas of the Lamoure silt loam which are so small that they could not be shown separately on the map. In the depressions or pond-like areas in the uplands where drainage is particularly poor, the surface soil is almost black in color and contains a particularly large amount of organic matter. In fact, there may be an inch or more of dark brown peat or black fibrous muck. The surface soil texture in these areas is a silt loam to a silty clay and the black color may extend to a depth of 3 feet or more. The topography of the Lamoure silty clay loam is generally flat with a slight slope toward the streams. The areas are subject to overflow and drainage is very poor.

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Very little of the type has been reclaimed by drainage and brought under cultivation. The greater part of it is utilized for producing wild hay. Corn and oats are grown to a small extent, corn yielding 30 to 50 bushels per acre and oats 30 to 55 bushels. In favorable seasons corn may yield more than on the adjacent uplands. Many oat varieties are unsatisfactory owing to lodging but Iowa 103 and Iowa 105 may be grown successfully. Some buckwheat has been grown and flax is sometimes utilized on newly reclaimed land.

The Lamoure silty clay loam is naturally a very productive soil after it has been drained. At least in seasons of normal rainfall yields of cultivated crops may be entirely satisfactory. Such land, however, must be adequately drained before being utilized in any way for cultivated crops. It should also be protected from overflow and when these operations are followed yields of general farm crops should be entirely satisfactory without other special treatment. A small application of farm manure might be of value on newly drained areas to stimulate the production of available plant food. The soil is usually high in lime but if in any case this is not true and it shows an acid reaction, lime should be added. Phosphorus fertilizers will be needed in the future when the soil is brought under cultivation and crops are being removed annually.

WABASH SILTY CLAY (27)

The Wabash silty clay is the second largest bottomland type in the county and the fourth largest individual type, covering 3.8 percent of the total area. It occurs mainly along the West Fork Des Moines river with a few small areas along Prairie creek, Cylinder creek, Jack creek and near the head of Medium lake. There is one continuous area of this type along the West Fork Des Moines river extending from the northern boundary of the county near Graettinger to a point three miles west of Rodman and another area extending from a point south of Rodman and following the course of the river until it flows out of the county on the Pocahontas line. These areas are extremely irregular and variable in width, in some cases being very narrow and widening out to a width of almost two miles just south of Emmetsburg.

The surface soil of this type is a dark brown to almost black silty clay, 12 to 15 inches in depth. It is underlaid by a dark slate or black waxy clay in some places faintly mottled with yellow and gray below 24 inches. There are some variations of this type along Prairie creek, from West Bend south. The surface soil here is almost a silt loam and the subsoil is a gray to dark brown silty clay. In the area three miles west of Rodman there are small areas included in the type where the surface soil is lighter in texture than the typical and the subsoil passes into a sandy loam or loamy sand below 30 inches. The surface of the soil is uniformly flat with a slight slope toward the stream. It lies from 8 to 12 feet above the normal water level of the river. Natural drainage is poor and the soil is subject to overflow.

About 10 percent of the type is in cultivation, the larger part being utilized for pasture or for the production of wild hay. A few forested areas are found along the river, the tree growth consisting principally of elm, oak, willow, and ash. Hay is the most important crop and yields of 1 to 1½ tons per acre are secured. Corn is grown to some extent on the cultivated portion and in favor-

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able seasons very satisfactory yields are obtained. Flax is sometimes grown on newly broken sod land and yields 8 to 10 bushels per acre.

The Wabash silty clay is principally in need of drainage and protection from overflow to make it a satisfactory soil for the growth of general farm crops. Drainage is absolutely essential and satisfactory crop yields cannot be insured unless the type is protected from overflow. Care must be taken in plowing and cultivating this soil to do so when it is not too wet or too dry, as in either case the physical condition of the soil will be injured. Small applications of farm manure would probably be of value on newly drained areas of this type. It is quite generally acid and should be limed. Phosphorus fertilizers will certainly be needed in the future and might be of value in certain cases even now. This type is naturally rich and with proper drainage and handling, very large crop yields may be secured.

CASS LOAM (18)

The Cass loam is the third largest bottomland type in the county being slightly smaller than the Wabash silty clay and covering 3.6 percent of the total area. It occurs in many areas of varying size along the West Fork Des Moines river and along Cylinder, Prairie and Pilot creeks. The largest continuous area is found along the course of the river west of Rodman. The second area of considerable size is found to the west of the river two miles south of Emmetsburg.

The surface soil of this type is a dark brown to black loam extending to a depth of 10 to 15 inches. The subsoil is a yellowish-brown sandy loam to sandy clay loam which grades into a layer of sand or sand and gravel below 30 inches. In some cases the surface soil is a black heavy loam to silty clay loam while in others the texture approaches a fine sandy loam. These variations from the typical soil are too small to show separately on the map. In its native state the surface of the soil is covered with a layer of black muck, 1 to 2 inches in depth. The stratified sand and gravel layer, which is characteristic of the Cass series, always occurs within the 3 foot section. The soil is level to gently sloping in topography and drainage is not entirely adequate. It is subject to overflow and unless protected from flood water cannot be utilized for general farm crops with any assurance of securing a satisfactory crop yield.

Only a small portion of the Cass loam is farmed, the greater portion of it being utilized for pasture or the production of hay. There are a few wooded areas, the tree growth consisting mainly of elm, maple and willow. In the cultivated areas corn, oats and flax are the principal crops, the latter being grown on newly-broken sod ground. There are also small acreages of barley, rye and buckwheat. By far the largest acreage is taken up by the hay, the greater portion of which is fed on the farms, but there is some sale of this product out of the county. On well drained areas corn yields on the average 30 to 50 bushels per acre, oats 30 to 45 bushels, flax 8 to 10 bushels and hay from 1 to 1½ tons per acre.

When protected from overflow and well drained, this type is quite satisfactorily productive. Small applications of farm manure would be of value when the type is newly drained and additions of lime would be of value when the soil shows an acid reaction which it ordinarily does and phosphorus fertilizers may

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Fig. 7. An area of peat and muck, with Clarion loam in the distance.

prove of value in some cases now but will undoubtedly be needed in the near future. The chief need of the type, however, is for drainage and protection from overflow.

PEAT AND MUCK (21)

There are numerous areas of peat and muck in all parts of the county, together covering 2.8 percent of the total area. They occur in depressed areas in the uplands and along intermittent drainageways where the drainage has been very poor and where probably in the past small lakes occurred. The largest individual area is found north of Lost Island lake. Peat and muck are not differentiated in this county, many areas showing the occurrence of peat in the center with an area of muck surrounding it.

Peat is a brown fibrous mass of partially decomposed vegetation. The material in the county is extremely variable depending upon the amount of decomposition it has undergone. In most of the areas it is 18 to 24 inches deep altho in a few instances it has been found to extend to a depth of 3 feet. The subsoil material is a black silty clay to brownish-gray fine sand or sand. Where the decomposition of peat has been so extensive that the material has become black in color and the structure of the plants going to make up the deposit has disappeared, the material is called muck. The areas of muck could not be mapped separately in this county owing to their small extent and hence they are all grouped under the combined head. The topography of peat and muck areas is flat and in many instances water remains on them for long periods. These areas are indicated on the map as ponds.

When these areas of peat and muck have been drained and cultivated for a few years they may be utilized for the production of general farm crops. Alsike clover and timothy are recommended as the most desirable crop on newly reclaimed areas. This crop may be utilized for hay or for pasture, the latter being preferable, as the trampling of the stock will compact the peat and bring it

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more quickly into decomposition. Oats are apt to lodge and corn will not do well until the peat areas have been under cultivation for several years. Rye grows well on reclaimed peat and potatoes also produce satisfactory crops. Onions, celery, cabbage, lettuce and some other vegetable crops are grown successfully on cultivated peat areas.

The chief treatment needed for areas of peat and muck is adequate drainage. Proper cultivation is then necessary. Fall plowing and deep plowing are recommended. Farm manure should not be applied except in very small applications to stimulate decomposition processes and the production of available plant food. Lime is not needed, as the peat is usually extremely well supplied with this material. The phosphorus content of peat is low and the application of phosphorus fertilizers may be of value in some cases and the use of special fertilizer brands may be very desirable where truck crops are to be grown.

CASS SILT LOAM (106)

The Cass silt loam is a minor type in the county covering only 1.5 percent of the total area. It occurs in the first bottoms of the West Fork Des Moines river, Cylinder creek and Prairie creek. The largest area is along Prairie creek east of Cylinder and rather considerable areas of the type occur along the river both north of Emmetsburg and south of this city.

The surface soil of the Cass loam is a black heavy silt loam to silty clay loam 6 to 8 inches in depth. The subsoil is a dark brown to grayish-brown sandy loam to sandy clay loam which grades at 20 to 30 inches into a loose textured yellow sand or mixture of sand and gravel. In some uncultivated areas the surface of the soil is covered with a thin layer of black muck. A few areas of Cass loam and silty clay loam too small to be shown separately on the map, are included in this type.

In topography it is practically flat, lying 10 to 13 feet above the normal level of the river. Along the creeks it lies 2 to 5 feet above the water level. Drainage is inadequate and the soil is subject to overflow.

Very little of this type is in cultivation, corn and oats being grown to some extent with fair yields in good seasons. Most of the type is used for the growing of hay or pasture, the hay being made up chiefly of wild grasses and yielding 1 to 1½ tons per acre.

The first treatment which this type needs to make it more productive is adequate drainage and then protection from overflow. The addition of small amounts of manure to newly drained areas would be of value to stimulate the production of available plant food constituents. The soil may be acid, in which case lime should be applied. It is not particularly well supplied with phosphorus and phosphorus fertilizers might be of value at the present time and certainly will be needed in the near future if the type is to be brought under cultivation and utilized for general farm crops.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

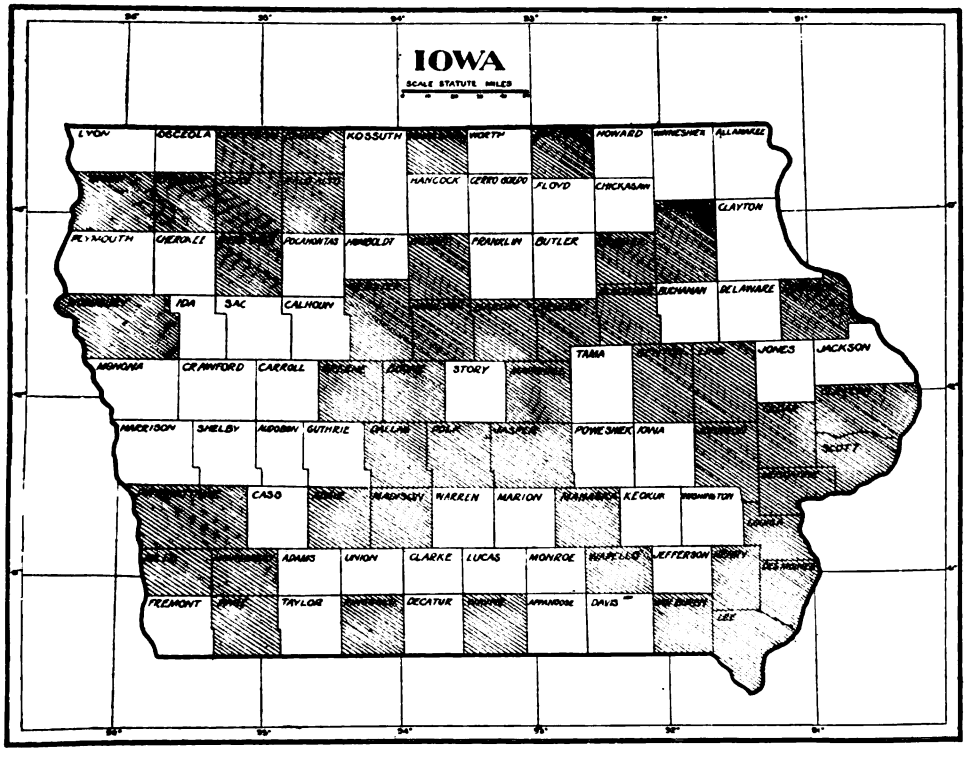

Fig. 8. Map of Iowa showing the counties surveyed.

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The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accummulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavail-*

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able. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant anaylses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

*Bulletin 150, Iowa Agricultural Experiment Station.

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Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between

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two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important

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in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 9.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are

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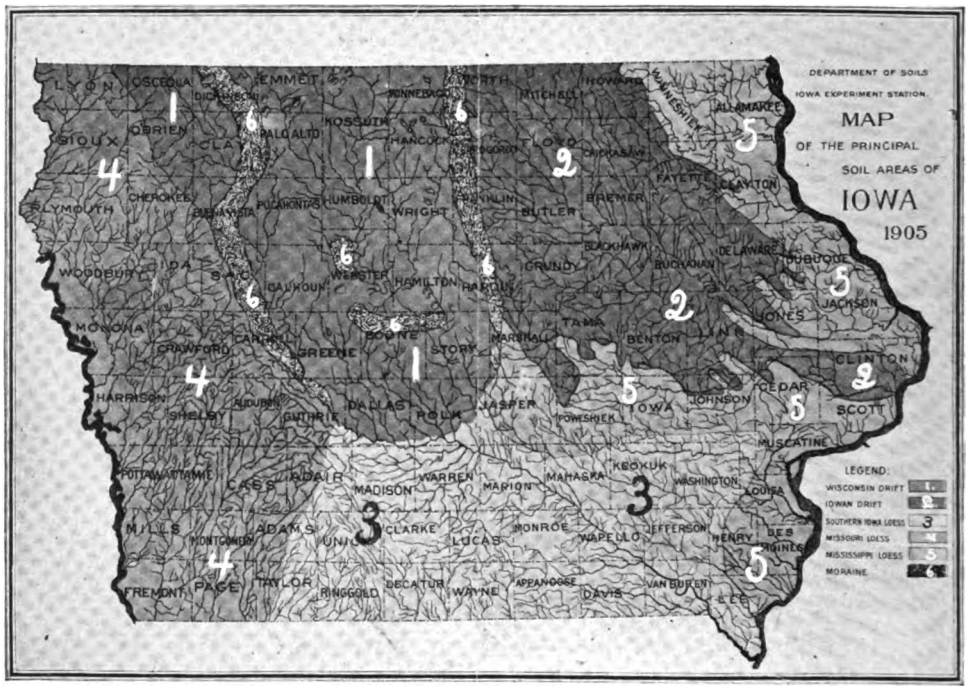

Fig. 9. Map showing the principal soil areas in Iowa

somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

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The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture of porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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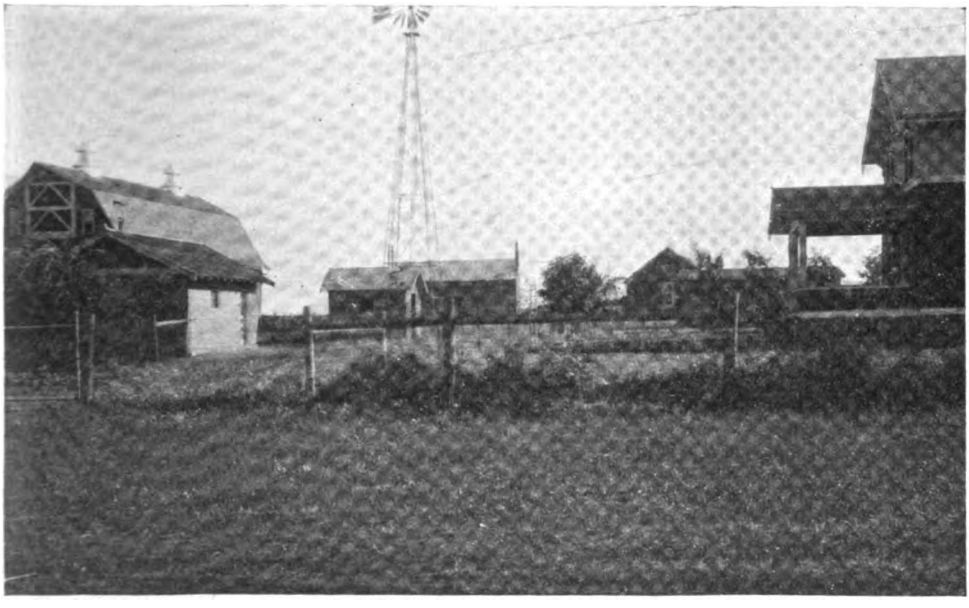
June, 1922 Soil Survey Report No. 23

SOIL SURVEY OF IOWA

Report No. 23—WINNEBAGO COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, W. G. Baker and G. H. Artis



Farmstead on Clarion loam, Winnebago county.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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WINNEBAGO COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, W. G. Baker and G. H. Artis

Winnebago county is located in northern central Iowa, bordering on the state of Minnesota, and almost in the exact center of the northern boundary of the state. It lies entirely within the Wisconsin drift soil area. Hence the upland soils of the county are all of glacial origin and the terrace and bottomland types also are derived from the drift material.

The total area of the county is 399 square miles, or 255,360 acres. Of this area 249,854 acres or 97.8 percent is in farm land. The total number of farms is 1,627 and the average size is 154 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land of the county:

Acreage in general farm crops	193,418
Acreage in pasture	57,500
Acreage in farm buildings, feed lots, and public highways	14,892
Acreage in waste land	5,956
Acreage in crops not otherwise listed	898

The type of agriculture commonly practiced in Winnebago county at the present time is general farming and includes the raising and feeding of cattle and swine. Dairying is practiced to some extent, also. The livestock industry is increasing in importance, particularly the feeding of hogs. On practically all farms the sale of hogs provides the largest part of the income. The sale of corn out of the county is not large and most of this crop is fed on the farms. Oats are sold more extensively to outside markets and there is some outside sale of other crops. The income from dairying is considerable and this industry is gradually becoming of more importance.

There is a rather large area of waste land in the county, much of which may be reclaimed and made productive with proper methods of soil treatment. In most instances infertility may be traced to inadequate drainage; the installation of tile and drainage ditches may provide for the reclamation of considerable areas. There are other causes of unproductiveness, however, and in some instances special methods of soil treatment must be practiced in order to make the soils satisfactorily productive. In a later section of this report, special treatments which are particularly desirable for individual soil conditions will be suggested. In special cases, for more or less abnormal conditions, advice regarding treatment will be furnished upon request by the Soils Section of the Iowa Agricultural Experiment Station.

The general farm crops grown in Winnebago county in the order of their importance are corn, oats, hay, potatoes, wheat, barley, alfalfa and rye. The average yields and value of these crops grown in the county are given in table I.

Corn is the most important crop, both in acreage and value. Average yields of corn amount to 47 bushels per acre. Under favorable seasonal and soil conditions, very much larger yields of this crop are frequently secured. In 1920

*See Soil Survey of Winnebago county, Iowa, by W. E. Tharp, of the U. S. Department of Agriculture, and G. H. Artis, of the Iowa Agricultural Experiment Station.

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TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN WINNEBAGO COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	73,200	29.3	47.0	3,440,000	$0.47	$1,616,800
Oats	57,500	23.0	47.0	2,702,500	0.36	972,900
Spring wheat	5,280	2.1	11.0	58,100	1.35	78,435
Barley	3,590	1.4	22.0	78,980	0.63	49,757
Rye	110	0.04	17.0	1,870	1.17	2,187
Hay (tame)	22,050	8.8	1.5	33,080	16.24	537,218
Hay (wild)	20,650	8.2	1.2	24,780	12.69	314,458
Alfalfa	70	0.02	4.0	280	19.23	5,384
Potatoes	968	0.39	149.0	144,232	1.22	175,963
Pasture	57,500	23.0	....	.....	....	.....

almost 30 percent of the farm land of the county was utilized for this crop. The larger portion of the corn produced is fed on the farms; much is sold in the local markets, and it is estimated that less than 10 percent is sold out of the county. There are more than 100 silos in the county and a good deal of the corn produced is used for silage.

Oats is the second crop in acreage and value, and is an important crop on practically every farm. Twenty-three percent of the total farm land of the county was in oats in 1920 and average yields of this crop amounted to 47 bushels per acre. A large part of the oats grown is sold and it is estimated that 40 to 50 percent of the production goes to outside markets. There seems to be a much larger sale of this crop from the rented than from the owned farms.

The production of hay in the county is large and the combined value of the tame hay and the wild hay almost equals the value of the oats crop. The wild hay consists of native grasses growing on poorly drained land which is unsuited for cultivated crops; 8.2 percent of the farm land of the county is in wild hay. The yield of tame hay in the county averages 1.5 tons per acre and the crop consists mainly of clover and timothy mixed. Some clover is grown alone, altho it is estimated that not more than 10 percent of the small grain acreage is sown to this crop. Practically all of the hay produced is utilized for feeding purposes.

Potatoes are grown on rather a considerable area with large average yields, making this a valuable crop. The production of potatoes, however, is sufficient only to supply the home demand.

Spring wheat is produced to some extent, with average yields of 11 bushels per acre, the varieties used being Marquis and Velvet Chaff. No winter wheat is grown. The growing of wheat is of very minor importance in the county.

Barley is produced on a small area, with good average yields, and there are also small areas of rye and alfalfa. The latter crop gives indications of becoming of value in the county and average yields of 4 tons per acre are reported. This crop should prove of particular value in connection with the dairy farming industry. Sweet corn is raised in the vicinity of Lake Mills and Forest City, and sold to the canning factories at those places. Average yields are estimated at from 4½ to 5 tons per acre.

*Iowa Yearbook of Agriculture 1920.

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Small apple orchards are maintained on practically all farms for home supply. The Northwestern Greening, Wealthy, Duchess, Tetofsky and Yellow Transparent are the most successful varieties. There are several small orchards near Forest City, but the commercial production of apples is not practiced to any considerable extent. Cherries, plums, goose-berries, currants, red raspberries and strawberries are grown, but these small fruits are not produced as extensively as they might be. There is very little fruit production on rented farms and the fruit industry in general is developed to only a small extent on the owned farms.

Some sorghum is raised and utilized for syrup, and some flax seed is produced.

The livestock industries of the county consist mainly of the feeding of hogs and cattle, and dairying. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the extent of the livestock industries of the county:

Horses, all ages	9,276
Mules, all ages	216
Swine on farms July 1, 1920	52,682
Swine on farms Jan. 1, 1921	41,230
Cattle (cows and heifers kept for milk)	12,327
Cattle (other cattle not kept for milk)	19,666
Cattle, all ages	31,993
Sheep (all ages on farms Jan. 1, 1921)	2,055
Sheep (shipped in for feeding, 1920)	1,248
Sheep (total pounds of wool clipped)	9,300
Poultry (total all varieties, Jan. 1, 1921)	204,163
Poultry (number dozen eggs received, 1920)	689,186

The feeding of swine is perhaps the most important livestock industry, the total number of hogs on the farms July 1, 1920, being 52,682. The sale of swine brings the largest income to most farms, and the greater portion of the corn crop is utilized as feed for the hogs. Cattle feeding is practiced to some extent, and a small number of sheep are shipped in for feeding.

The dairy industry is increasing in importance and on practically all the farms the sale of milk or cream provides considerable income. There are cooperative creameries in many of the towns; the total value of the dairy products sold out of the county amounts to many hundreds of thousands of dollars annually. In practically all cases the dairy industry is combined with general farming practice and the products of the farm are used very largely for feed and very little concentrates are purchased.

Poultry production is increasing in the county and the value of the egg production is considerable. Practically all of the eggs produced are sold in the local markets.

The value of land in Winnebago county is extremely variable, depending on the location with reference to towns and to railroad facilities, the improvements on the farms and natural soil conditions. The average price of the upland soils would range from $150 to $350 per acre. On the bottomland areas the price would, of course, be very much less, while a larger price is often secured for well improved farms.

The yields of general farm crops in Winnebago county have been fairly satisfactory, at least on the uplands, but in many cases more profitable yields might be secured by the adoption of better methods of handling the soils.

In many instances drainage conditions are not entirely satisfactory and when this is true, crop production will be low. It is necessary that many of the soils

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of the county be tiled and in some instances ditching also is needed, if crops are to be protected from injury due to excessive moisture. No fertilizer treatment will prove of value on land which is too wet and even if the drainage of an area proves an expensive operation, the increased yields of crops secured will more than warrant the outlay.

Some of the soils of the county are acid and applications of lime are necessary. The amount of lime is not large in any of the surface soils of the uplands and even if the soil is not acid at present, acidity will develop and lime will be needed in the future. All the soils of the county should be tested at regular intervals for lime requirement and this material should be applied as needed, if the best growth of crops, particularly of legumes, is to be secured.

The upland types in the county, with one exception, are not rich in organic matter and applications of farm manure would be of value for increasing crop yields. In many instances the application of farm manure to the soils of the Clarion series has proved of great value from the crop standpoint. This is particularly true for the rolling phase of the Clarion loam. Even on those types where the organic matter supply is large, farm manure may be applied to advantage if used in small amounts, especially if applied immediately following the drainage of the soil. The bottomland types are not in need of manure, except in small amounts, as suggested, except in the case of the so-called alkali spots, which frequently occur in areas surrounding muck and peat deposits. On such areas the application of manure after the area has been drained is very important, if the excess of alkali salts is to be removed. It should be emphasized that for the maintenance of fertility in all the soils of this county and the keeping up of the organic matter content, farm manure should be utilized and all crop residues should be returned to the land. It may become necessary to use some leguminous crops, as green manures, also, if farm manure is not available, to keep up the nitrogen content of the soils, which must also be maintained if large crops are to be grown continuously.

The phosphorus content of Winnebago county soils is inadequate to supply any large number of crops, and additions of phosphorus fertilizers will become necessary in the future in all cases. There are many instances when phosphorus might be of value on these soils at the present time and farmers are urged to test the value of applications of rock phosphate or acid phosphate under their own soil conditions.

Erosion is active in some portions of the county, particularly in the rolling phase of the Clarion loam and in the steep phase of the same type. In many instances the washing away of the surface soil is being carried on by what is known as sheet erosion.

THE GEOLOGY OF WINNEBAGO COUNTY

The bed rock underlying the soils of Winnebago county has been buried so deeply under deposits of glacial drift that there is no effect of this rock material on the character of the soils. Hence it is unnecessary to consider the early geological history of the county prior to its invasion by the glaciers.

At least twice during the glacial age, great glaciers swept down from the north and, upon their retreat, left behind vast deposits of glacial drift or till. The

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first of these drift deposits, known as the Kansan, consists mainly of what is now called blue clay and is extremely variable in depth. Apparently the original topographic features of the county were very largely obliterated when the Kansan till was deposited and the surface of the deposit was more or less level. This blue clay is very infrequently exposed and there is practically no effect from its occurrence upon the soil conditions in the county.

The later glacier, known as the Wisconsin, passed over the surface of the Kansan and the deposit of drift which it left behind upon its retreat covered deeply the earlier glacial material. It is from this Wisconsin drift that the soils of the county are derived and, even where erosion has been rather active for many years, there is only very infrequently any evidence in the surface soil of the earlier drift deposit. The Wisconsin drift is a pale yellow or light buff silt, clay and sand, containing some stones and boulders. In most instances 70 to 80 percent of the material is made up of silt and clay, the remainder being composed of medium and coarse sand. This buff-colored material is highly calcareous and in many places limestone fragments are numerous. Gravel and stony material of several kinds occur thruout the deposit, but in general the number of stones and boulders is small and they cause no difficulty in farming operations. On the morainic ridges, however,—those areas which mark the edge of the glacier,—there may be considerable deposits of stony material, with pockets of gravel. The surface material of this drift deposit has been very largely modified by weathering and the growth of vegetation and the color of the surface soil is generally dark brown to black. Much of the lime has been washed from the surface soil and, in the case of the Clarion soils, the most important types in the county, the surface soils are generally acid, while the subsoils may show a content of lime which in some cases is rather considerable.

The depth of this Wisconsin drift layer is extremely variable, ranging from 6 to 30 feet, on the average, for the entire county. There may be some instances where the blue clay of the Kansan is encountered at a depth of from 5 to 6 feet, but in general the Wisconsin material occurs in rather deep layers. Apparently the earlier topographic features of the Kansan deposit were not entirely obliterated by the Wisconsin glacier and occasionally on the knobs and mounds which occur in the county, there are remnants of the Kansan topography, with layers of Wisconsin drift extending over their surface. Gravel pockets, evidently of Wisconsin origin, frequently occur, sometimes on low knolls, and again at higher points. Occasionally these deposits may extend to a considerable depth. They are of no importance, however, from the soil standpoint, as their occurrence is entirely local and they are usually so far beneath the surface that they exert no effect on the soil conditions.

On the more level portions of the county the accumulation of organic matter in the soils has been greater and, as the drainage on these areas has been poor, lime has not been removed to such a large extent, and the Webster soils of the level uplands are consequently characterized by a black color and high lime content. On the more rolling uplands the accumulation of organic matter has been less and the color of the Clarion soils is usually a dark brown. These soils as a rule contain some lime in the lower layers and the subsoil is frequently a grayish-brown in color. In many cases, however, no lime is found to a depth of

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3 feet, and thruout the areas of Clarion soils, there are areas which should really be mapped in the Carrington series. It is quite impossible to show these small areas of Carrington on the map, so they are included with the Clarion soils.

The terrace and bottomland types are derived from the drift soils of the uplands, and resemble them in appearance and general characteristics. The Waukesha loam on the second bottoms is very much like the Clarion loam, except that the subsoil is usually not calcareous, while the Fargo silt loam, representing an old lake terrace, resembles the same type of the Webster series. The area of bottomland in the county is small and besides the area of muck, peat and meadow, there is only one soil type mapped. This is a highly calcareous soil belonging in the Lamoure series and resembling the same type of the Webster series.

All the soils of the county, therefore, bear evidence of the more recent geological history, and this newer deposition of soil material, taken together with the more or less generally level topography and consequent accumulation of organic matter, indicates that the soils are comparatively fertile and that crop yields on them should be entirely satisfactory.

PHYSIOGRAPHY AND DRAINAGE

The topography of the western part of the county as a whole is almost level to gently rolling. The hills and ridges are low and rounded. The general slope of this upland plain is toward the southwest, and there is some drainage in that direction thru sluggish streams. In the eastern part of the county, the topography is strongly rolling to moderately hilly. This topographic condition is

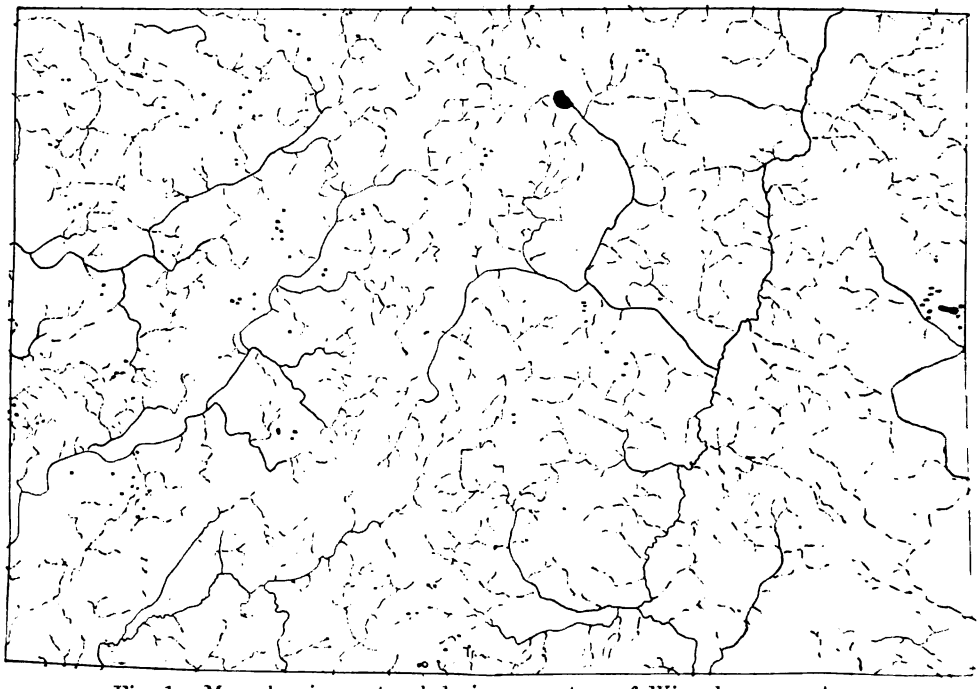

Fig. 1. Map showing natural drainage system of Winnebago county.

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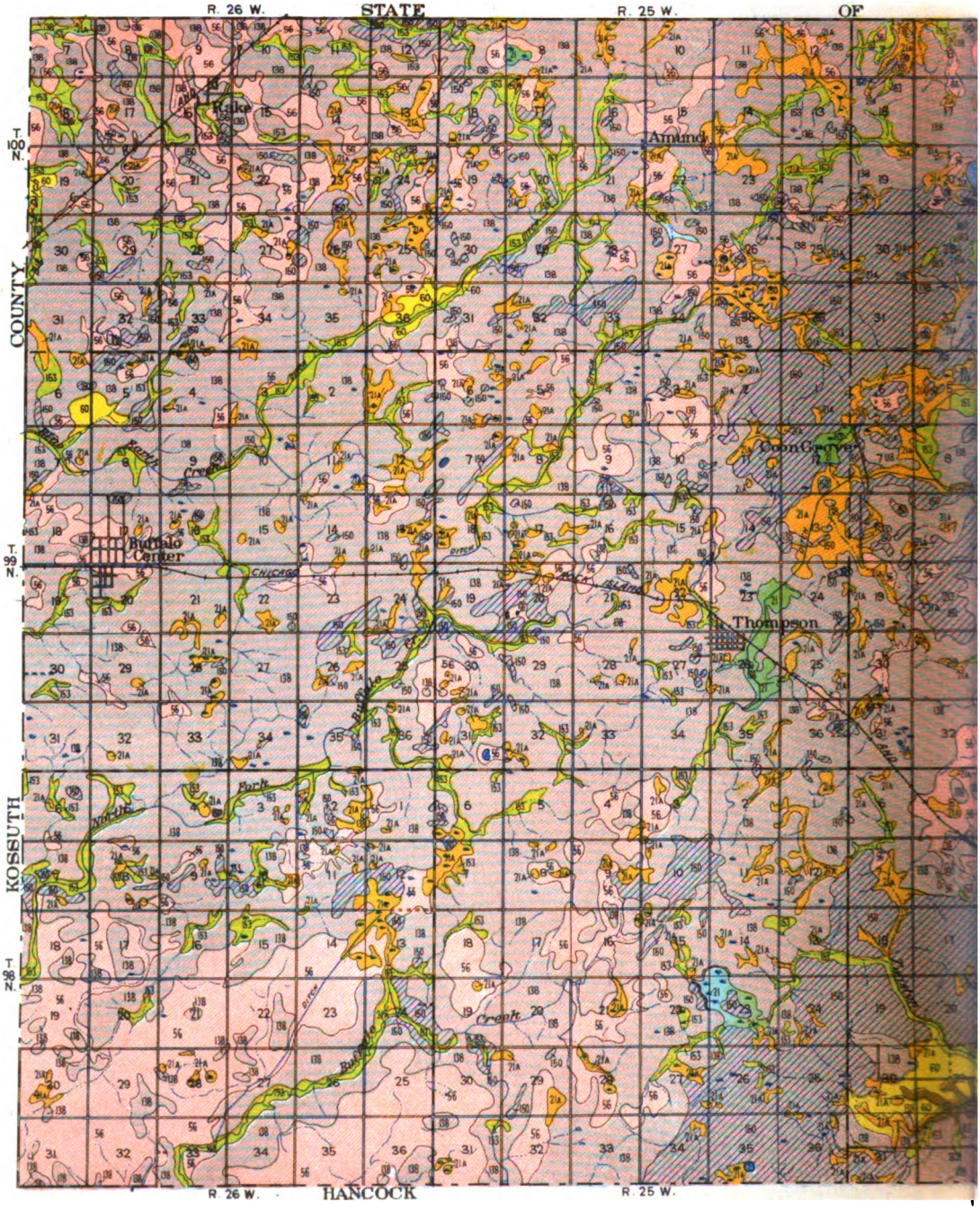
SOIL MAP OF W

Thomas D. Rice, Inspector, Northern Division. Su
Agriculture, in charge, and C. H. Arb

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut, in charge Soil Survey.



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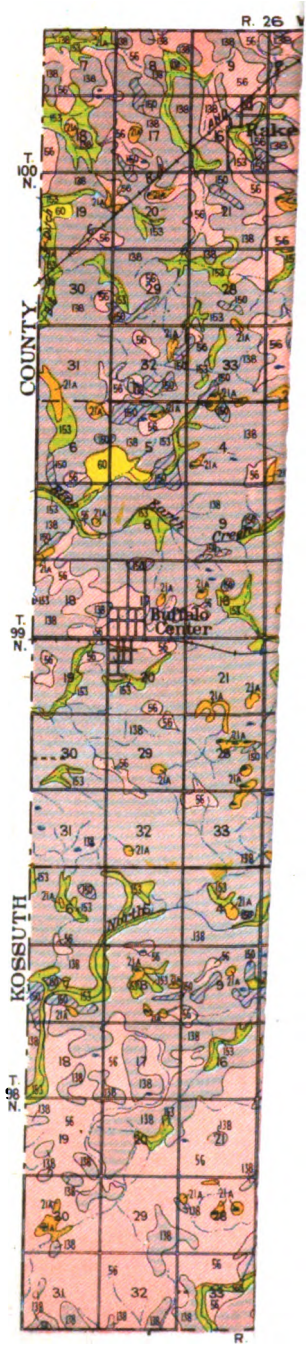

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known as the morainic topography and is characterized by knobby morainic hills and ridges, with more or less sharply defined outlines. These hills and ridges are irregular in distribution, occurring over rather large areas in the eastern part of the county and at scattered points in the western part. They are most pronounced in the vicinity of Forest City and north of Lake Mills. This rougher portion of the county is mapped as the rolling phase of the Clarion loam and is quite distinct topographically from the typical Clarion. The boundary lines between these types are generally very plain.

The drainage of the entire county is inadequate. The streams, flowing thru shallow channels, provide insufficient drainage even in their immediate locality. Blue Earth creek, North Fork Buffalo creek and Buffalo creek are the only natural drainage channels in the western part of the county and form only a very imperfect drainage system for that territory. Drainage conditions are little better in the rougher portions of the eastern part. Lime creek flows across the county from north to south, but it has few important tributaries and does not bring about adequate drainage, other than in a comparatively small area. Twister Branch, near Forest City, and Pike's Run, north of Leland, are the only important tributaries to this creek. In the southeastern portion of the county, Beaver creek drains a small area, likewise inadequately.

Ditches have been installed in many places in the county and provide artificial drainage for rather considerable areas. The accompanying map illustrates graphically the poor drainage conditions in the county, showing the very poorly developed system of streams and intermittent drainage ways, and the soil map likewise gives evidence of the poor drainage conditions. Muck occurs in all parts of the county in small, irregular-shaped areas, many of which are still under water, as indicated on the map by swamp symbols,—definite evidence of poor drainage. Then, too, there are considerable areas of peat, particularly in the old lake beds in the eastern part of the county, indicative of the swampy condition of the land in the past. In addition to these areas of muck and peat, there are numerous small areas and some larger areas of the Webster clay loam, a level, poorly-drained upland type. These areas of peat and muck and poorly-drained Webster clay loam are surrounded by the Clarion loam or the rolling phase of the same type, and from the close association of these types it is evident that the drainage of the Clarion soils may be inadequate in many cases. Tiling is necessary in many parts of the county and there is undoubtedly need for the installation of more ditches, as so many times tile cannot be utilized until a ditch has been provided to carry away the water draining from the tile. It is absolutely necessary that artificial drainage channels be provided to make up for the inadequate natural drainage system of the county.

THE SOILS OF WINNEBAGO COUNTY

The soils of Winnebago county are grouped into three classes, according to their origin and location. These are drift soils, terrace soils, and swamp and bottomland soils.

Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glaciers retreated. They are variable in

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composition and may contain pebbles and boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them, or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly-drained areas, or along streams, and they are subject to more or less frequent overflow.

The extent and occurrence of these three groups of soils in Winnebago county are shown in table II.

By far the largest portion of the county is covered by the drift soils, 83.9 percent being in drift uplands. There is a very small acreage of terrace types, only 2.5 percent of the county being covered by these soils. The swamp and bottomland soils are more extensive, covering 13.6 percent of the total area and occurring in many small areas in all parts of the county.

There are five individual soil types in the county and these, together with the rolling phase of the Clarion loam, the steep phase of the same type, and the muck, peat and meadow, make a total of ten separate soil areas. There are four drift soils, including the phases mentioned, two terrace types and four swamp and bottomland soils. These various soil types are distinguished on the basis of certain characteristics, which are described in the appendix to this report, and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Clarion loam is the largest individual soil type, covering almost half of the total area. The rolling phase of the Clarion is the second largest soil in the county, covering more than one-fourth of the total area. The typical Clarion and the rolling and steep phases together cover almost three-fourths of the county, 73.2 percent of the total area. The Webster clay loam is the third largest soil type in the county, covering 10.7 percent of the total area. There is a rather considerable total area of muck, 5.2 percent of the county being occupied by this soil. Almost the same area is covered by the Lamoure silt loam, the only true soil type occurring in the bottoms. There are several areas of peat, together making a total of 2.7 percent of the total area.

The topography of the uplands of the county is very closely related to the soil type occurring on them. Where the Webster clay loam occurs, the topography is level to depressed; the typical Clarion loam shows a gently undulating topography, while the rolling phase, as the name indicates, has a much more pronounced rolling topography. The steep-phase Clarion represents the extreme topographic condition. The terraces and bottoms of the county are topographically level to depressed. In those portions of the county where the Clarion loam and Webster clay loam are the important types, the drainage conditions are unsatisfactory and tiling and ditching are generally necessary. Where the rolling

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN WINNEBAGO COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	214,208	83.9
Terrace soils	6,464	2.5
Swamp and bottomland soils	34,688	13.6
Total	255,360	....

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TABLE III. AREAS OF DIFFERENT SOIL TYPES IN WINNEBAGO COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
138	Clarion loam	117,504	
150	Clarion loam (rolling phase)	68,928	73.2
151	Clarion loam (steep phase)	576	
56	Webster clay loam	27,200	10.7
	TERRACE SOILS		
60	Waukesha loam	4,416	1.7
152	Fargo silt loam	2,048	0.8
	SWAMP AND BOTTOMLAND SOILS		
21a	Muck	13,312	5.2
153	Lamoure silt loam	13,248	5.2
21	Peat	6,912	2.7
20	Meadow	1,216	0.5
	Total	255,360	....

phase of the Clarion occurs, the drainage conditions are better, but even in such a topography, artificial drainage is sometimes needed. The terrace types and swamp and bottomland types are level in topography and generally in need of artificial drainage if they are to be made properly productive.

THE FERTILITY IN WINNEBAGO COUNTY SOILS

Samples were taken for analyses from each of the soil areas in Winnebago county except the steep-phase Clarion, the peat, the muck and the meadow. The more extensive soil types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samples were taken with the greatest care that they should represent the particular soil types and that variations due to local conditions and previous treatments should be eliminated. The samples were drawn at three depths, 0" to 6 2-3", 6 2-3" to 20", 20" to 40", representing the surface soil, the subsurface soil, and the subsoil, respectively.

Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods, and the Veitch method was followed for the limestone requirements. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type and represent, therefore, the averages of four to twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is somewhat variable, ranging from 1,577 pounds in the rolling phase Clarion loam, up to 3,414 pounds in the Fargo silt loam. There is no apparent relation between the phosphorus content of the soils and the various soil groups. The average of the terrace types and the swamp and bottomland soils is somewhat higher than that of the upland soils, but the differences are not great. The variations within the various groups are larger than the variation between groups. There does seem

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TABLE IV. PLANT FOOD IN WINNEBAGO COUNTY, IOWA, SOILS

Pounds per acre of 2,000,000 pounds of surface soil (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
138	Clarion loam	1,910	4,591	54,822	Trace	1,932
150	Clarion loam (rolling ph.)	1,577	3,951	49,466	0	2,705
56	Webster clay loam	3,331	8,444	104,909	2,025	Basic
	TERRACE SOILS					
60	Waukesha loam	1,980	6,584	88,600	0	1,546
152	Fargo silt loam	3,414	11,936	242,618	21,582	Basic
	SWAMP AND BOTTOMLAND SOILS					
153	Lamoure silt loam	2,505	10,592	126,119	14,581	Basic

to be some relation, however, between the individual soil types or between the soil series and texture. Thus, the Webster clay loam is much higher than the Clarion soils and the Fargo silt loam is higher than the Waukesha loam. There are not enough types of the same series in this county to permit of any extended comparisons from the texture standpoint and it merely should be noted that the rolling phase of the Clarion is lower than the typical Clarion. In general, it seems that variations in phosphorus supply in the various soils of this county may be related to the topographic condition, at least in part. But the soil texture undoubtedly affects the phosphorus content, also. Thus it might be expected that the Webster soils would be higher in phosphorus than the Clarion soils, owing to their more level topography and generally poorly-drained condition and also owing to the fact that crop production has been less on these types in the past because of their inadequate drainage. The texture of the soil, however, is important and a clay loam would naturally contain somewhat more phosphorus than a loam, especially when a comparison is made between these types in the Webster series and the Clarion series. Hence there are several reasons for the better supply of phosphorus in the Webster clay loam than in the Clarion soils. A similar comparison might be made between the Fargo and the Waukesha soils. The Fargo silt loam occurs in poorly-drained depressions. Crop production has been less, drainage has been poor and hence the phosphorus content is naturally higher than in the Waukesha loam. Furthermore, the silt loam might be expected to contain more phosphorus than the loam.

In general, there is no large supply of phosphorus in the soils of Winnebago county and phosphorus fertilizers will undoubtedly be needed in the near future if satisfactory crop yields are to be secured. Even if these materials are not of large value at the present time, phosphorus must be considered in planning systems of permanent fertility. The total supply of phosphorus in soils is not a definite measure of the phosphorus which is available for crop use, but merely serves as an indication of the amount which may be available for the use of future crops. It is generally assumed, however, that if the soil conditions are satisfactory and there is a reasonably large total supply of phosphorus, sufficient of the element will be changed to an available form to provide for crop growth. On the other hand, if the phosphorus supply is low in soils, the production of available phosphorus is almost certain to be insufficient. It is evident, there-

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fore, that phosphorus fertilizers may prove of value on some of the soils of Winnebago county at the present time. Farmers are urged to test these materials on small areas on their own farms and thus determine for their particular conditions the need of phosphorus and which phosphorus fertilizer can be used most profitably.

The nitrogen content of the soils of the county is quite as variable as is the phosphorus supply, but the amounts of nitrogen are very much greater. There is no relation apparent between the nitrogen in the various types and the different soil groups which should be considered conclusive, owing to the fact that the number of soil types is small. The terrace soils and swamp and bottomland soils are higher in nitrogen than the upland types, which, of course, is due primarily to the fact that these soils have been cropped to a smaller extent and have lost less nitrogen by drainage. The differences in nitrogen content seem to bear more relation to the soil series or to the particular type. Thus the Webster clay loam is much better supplied than the Waukesha loam. This might be expected because of the characteristics which serve to distinguish the Webster and Fargo series from the Clarion and Waukesha soils. There is, however, an additional reason for the greater nitrogen content of the Webster and Fargo soils in this county, and this is that the types in these series are heavier-textured than the Clarion and Waukesha soils which are mapped in the county. In general, it might be expected that soils of a heavy texture and level to depressed topographic position, with consequent poor drainage, would contain more nitrogen, a condition which is found actually to exist in this county.

It is evident from these analyses that the soils of the county are in general fairly well supplied with nitrogen; in some cases there is a large amount present. This does not mean, however, that nitrogen may be disregarded in systems of permanent fertility. If the nitrogen content of the soils is to be kept up continuously, some nitrogenous fertilizing materials must be used at regular intervals. Farm manure returns to the soil quantities of nitrogen which are removed by the growing crops and is therefore an important nitrogenous fertilizer. On the rolling phase of the Clarion loam there is more need for this material than on the other types in the county. The typical Clarion loam and the Waukesha loam would also respond to farm manure and it is very necessary that the nitrogen content be maintained on these types. On the Webster, Fargo and Lamoure soils, manure should be used only in small amounts and never preceding a small grain crop, to avoid causing the grain to lodge. Small applications of manure, however, are frequently desirable on these types when they are thoroly drained and brought under intensive cultivation. The use of crop residues aids in keeping up the nitrogen content of the soil and these materials should never be wasted.

On the grain farm where manure is not available for use, and on the livestock farm where insufficient manure is produced for all the land, the nitrogen content of the soils may be kept up by turning under all or part of well-inoculated leguminous crops. Legumes, when well inoculated, derive a large part of their nitrogen from the air and when turned under in the soil, serve to increase its nitrogen content. Where the entire crop is removed, there would be no increase of nitrogen in the soil; neither would there be any reduction. Where the

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seed only of the legume is removed, there may be considerable addition of nitrogen to the soil and if a portion of the crop is returned, the nitrogen in the soil may be increased in proportion to the amount of crop turned under, depending, of course, upon the thoroness of inoculation.

There is a rather distinct relation between the nitrogen and organic carbon in most soils. The organic carbon is a measure of the organic matter in soils and the color of the soil indicates quite definitely the amount of organic matter and indirectly, therefore, the content of organic carbon and nitrogen. If the soil is black in color, the amount of organic carbon and nitrogen present is high. If the soil is light in color, the supply of these constituents may be low. The soils of Winnebago county are all dark in color, many of them black; hence, the supply of organic carbon in the various soils might be expected to be considerable. This is actually the case and the amount of organic carbon is found to range from 49,466 pounds to 242,618 pounds. Very much the same relations hold true for the organic carbon in the various soil types as in the case of nitrogen. The soils of the Webster, Fargo and Lamoure series are very much higher in organic carbon than the Clarion and Waukesha soils, just as they are higher in nitrogen. This is indicated by the darker color of these types and is undoubtedly due to the heavier texture and more level to depressed topographic condition.

The relation between the carbon and nitrogen in soils gives rather definite evidence of the rate at which plant food is being made available. In the soils of this county it seems that there should be a satisfactorily rapid production of available plant food, judging from the relation between the carbon and nitrogen. However, in all instances where drainage is poor, small applications of manure seem to be of particular value, probably because of the stimulation of available plant food production. Hence it would seem that in many of the soils somewhat abnormal conditions will prevent the best production of available plant food constituents, in spite of the fact that the relation between nitrogen and carbon seems to be satisfactory. The stimulation of bacterial action and greater production of available plant food may explain the beneficial effects noted from the use of manure on soils which are abundantly supplied with organic matter, black in color, and apparently not in need of its use. Many of the soils of this county will respond to additions of farm manure and this material should be used especially on the Clarion soils, and with more care on the dark colored types, if the organic matter content is to be kept up. Under adequate drainage conditions and intensive cropping, the loss of organic matter from soils may be very rapid, and farm manure is the cheapest and most natural method of making up this loss.

Crop residues should all be utilized as an additional means of keeping up the organic matter supply, and on the grain farm the proper handling of the legume crop of the rotation is necessary in order to supply organic matter to the soil. By the use of these materials in addition to farm manure, or as substitutes for that material, the organic matter content of the soils of the county may be kept up under any system of farming.

There is no large amount of inorganic carbon in the surface soil of any of the upland types in the county. The Fargo and Lamoure soils, however, show con-

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siderable amounts of this constituent in the surface soils and the Webster clay loam shows a small content. The Clarion and Waukesha soils are acid in the surface soils, but not to any great extent. In fact, the lime requirement of these types averages only about one ton. Hence, while the soils of the Webster, Fargo and Lamoure series show no need of lime, the Clarion soils should be tested for acidity and lime applied as shown to be necessary. The same may be said of the Waukesha loam and there are probably cases, also, where the Webster clay loam is slightly acid and in need of lime. However, in general this latter soil type is basic in reaction and lime is not needed. The need of lime in Winnebago county may be considered to be confined to the Clarion and Waukesha series, and the amounts required to remedy the acid conditions are comparatively small. With better drainage conditions in the county, and greater crop production, lime will disappear from these soils more or less rapidly and the soils will become increasingly acid in reaction. It is very important, therefore, that these soils be tested at regular intervals and lime applied as shown to be necessary. Legumes will not make the most satisfactory growth in acid soils and even if the surface soil only is acid, it is important to apply lime in order that the crop may get a good start and grow well in its early stages. Later, the legume roots may penetrate to the lower soil layers where lime frequently occurs. Lime seldom moves upward in the soil and even if the lower layers are high in carbonates, the surface soil must be neutralized by the use of lime if legume growth is to be satisfactory. It is urged, therefore, that farmers in Winnebago county test their soils in the Clarion and Waukesha series at regular intervals and determine their lime requirement, making the necessary application preceding the legume of the rotation.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre. Unless there are very large amounts of plant food present in the lower soil layers, there is little effect upon the fertility of the soil. Hence the analyses of the surface soils generally indicate quite definitely the plant food supply of the soil and, indirectly, its crop-producing power. The lower soil layers in Winnebago county are not extremely high in any plant food constituents, in general not higher than the

TABLE V. PLANT FOOD IN WINNEBAGO COUNTY, IOWA, SOILS

Pounds per acre of 4,000,000 pounds of subsurface soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
138	Clarion loam	2,386	5,175	65,362	Trace	3,348
150	Clarion loam (rolling ph.)	2,918	4,540	51,066	0	5,666
56	Webster clay loam	4,103	5,585	73,678	16,321	Basic
	TERRACE SOILS					
60	Waukesha loam	3,892	5,772	71,600	0	1,546
152	Fargo silt loam	4,027	10,004	197,900	20,100	Basic
	SWAMP AND BOTTOMLAND SOILS					
153	Lamoure silt loam	3,757	7,594	104,316	35,684	Basic

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TABLE VI. PLANT FOOD IN WINNEBAGO COUNTY, IOWA, SOILS

Pounds per acre of 6,000,000 pounds of subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
138	Clarion loam	3,306	3,838	46,418	36,982	Basic
150	Clarion loam (rolling ph.)	3,057	3,362	39,000	0	5,828
56	Webster clay loam	4,330	3,026	40,482	80,118	Basic
	TERRACE SOILS					
60	Waukesha loam	4,970	1,848	32,784	2,628	Basic
152	Fargo silt loam	6,081	11,346	176,772	107,616	Basic
	SWAMP AND BOTTOMLAND SOILS					
153	Lamoure silt loam	5,374	5,298	77,286	42,714	Basic

surface soils, so the fertility of the soils is influenced very little by the different subsoil conditions. It is not necessary to consider these analyses in detail, but attention may be directed merely to the fact that the needs of the soils, as indicated by the analyses of the surface types, are very largely borne out by the results on these lower soil layers.

Phosphorus fertilizers will be needed in the future and might possibly be of value in some cases now. The supply of organic matter and nitrogen is considerable in most instances, but farm manure, crop residues and leguminous crops must be utilized if the supply of nitrogen and organic carbon is to be kept up in the various soils. The supply of these constituents is not so large that crop production will go on indefinitely without any return. In most cases the lower soil layers in the county are well supplied with lime and show a basic reaction. Only the rolling-phase Clarion does not show a large amount of lime according to these analyses, but in many instances lime does occur in the three-foot section in this type, as is evident from other analyses. The lime content in the subsoil of this type, however, is extremely variable in depth, occurring many times below the three-foot section. The particular samples of the type analyzed here do not show lime in the three-foot section, but probably the lime layer would have been encountered at a slightly greater depth. In several of the soils the supply of inorganic carbon in the subsoils is very large, but as has been noted, the inorganic carbon in the lower soil layers has little effect on the surface soils and if they are acid, lime should be applied as needed. When these soils have been drained for a longer period and lime has been washed out and removed by crops, there will be a greater need for the use of this material. For the present it can merely be suggested that the surface soils of the Clarion and Waukesha series should be tested at regular intervals and lime applied whenever necessary.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Winnebago county in the attempt to learn something of the fertilizer needs of the soils and to secure indications of the value of certain fertilizing materials. These experiments were carried out on the Clarion loam and the Webster clay loam, the two most important types in the county. The treatments used in the experiments included the application of manure, lime, rock phosphate, acid phosphate and a complete

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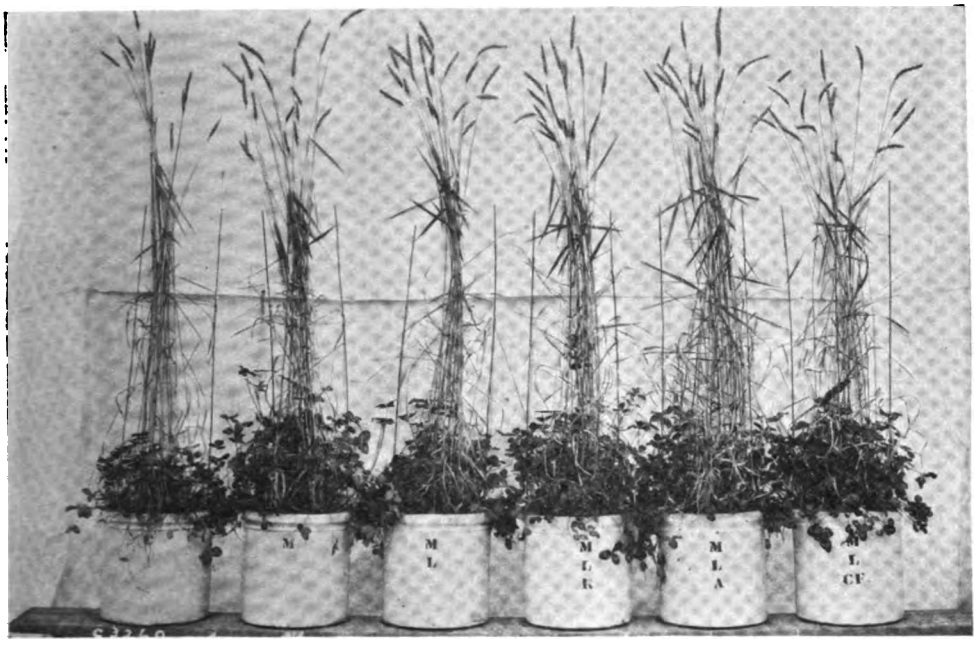

Fig. 2. Greenhouse experiment, wheat and clover on Clarion loam.

commercial fertilizer. The amounts of these materials applied were the same as are used in the field tests and the results of these greenhouse experiments may be considered to indicate rather definitely the results which would be secured in the field. Manure was applied at the rate of 8 tons per acre; lime was added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the experiments, clover being seeded about one month after the wheat was up.

The results of the experiment on the Clarion loam are given in table VII, the figures being the averages on the yields on the duplicate pots. Manure brought about very distinct increases on the wheat grown on this soil and the clover crop was also increased materially. The increase, however, was much more pronounced with the wheat. The addition of lime along with manure had a slight effect on the wheat, but showed no influence on the clover. This is rather surprising, as ordinarily the beneficial effects of lime are shown on the legume crop

TABLE VII. GREENHOUSE EXPERIMENT, CLARION LOAM, WINNEBAGO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	11.75	52.16
2	Manure	17.25	58.96
3	Manure+Lime	20.00	58.96
4	Manure+Lime+Rock phosphate	20.00	68.04
5	Manure+Lime+Acid phosphate	20.00	58.96
6	Manure+Lime+Complete commercial fertilizer	23.25	68.04

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and not on the grain crop. In general, farm experience shows the beneficial effect from the application of lime on clover and it is recommended that the need of this soil for lime be determined before clover is grown and that the proper application of lime be made as found necessary.

The application of rock phosphate and acid phosphate showed no effect on the wheat, but the rock phosphate brought about an increase on the clover. The complete commercial fertilizer increased both the wheat and the clover crop. It would seem from these results, therefore, that the Clarion loam will respond profitably to applications of farm manure. Lime should be used when the soil is acid in reaction and there are indications that phosphorus fertilizers may prove of value. The results obtained in this test are not sufficiently complete to permit the drawing of definite conclusions regarding the relative value of rock phosphate, acid phosphate and the complete commercial fertilizer. Further tests in the field are necessary before definite conclusions along this line may be drawn. As far as the complete commercial fertilizer is concerned, it may yield profitable returns in some instances, but it is not expected that a complete brand will prove as profitable as a phosphorus carrier, inasmuch as the expense involved is much larger and the soils are not as much in need of nitrogen and potassium as they are of phosphorus. It seems probable that phosphorus fertilizers will yield greater returns economically than the complete brands. Tests on the individual farm are urged to determine the relative value of rock phosphate and acid phosphate.

The second greenhouse experiment was on the Webster clay loam and the yields obtained are given in table VIII. Again the effect of manure is definitely

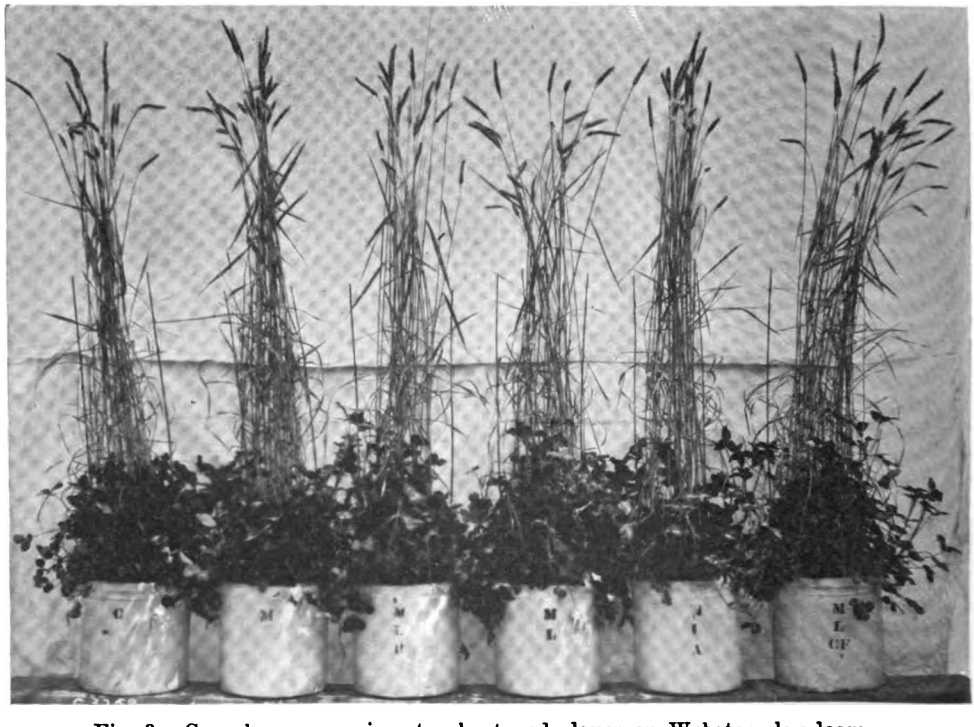

Fig. 3. Greenhouse experiment, wheat and clover on Webster clay loam.

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TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER CLAY LOAM, WINNEBAGO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	18.00	70.25
2	Manure	22.00	74.84
3	Manure+Lime	22.75	74.84
4	Manure+Lime+Rock phosphate	26.00	77.11
5	Manure+Lime+Acid phosphate	23.00	....
6	Manure+Lime+Complete commercial fertilizer	25.00	79.38

shown, the yields of both the wheat and the clover being increased very definitely by the application. In spite of the fact that this soil is comparatively well supplied with organic matter, the addition of farm manure seems to prove of value, probably due, as has been suggested, to the stimulation of bacterial action and the greater production of available plant food. The particular sample of soil used in this experiment was slightly acid in reaction, hence lime was applied. The amount of acidity was so small, however, that crop yields were not influenced by the application of the lime. In general this soil is not in need of lime and this material would not need to be used. Wherever the type is acid, however, to a definite extent, an application of lime should be made. As the soil is brought under more intensive cultivation and is better drained, the loss of lime will increase and the need of testing the soil and making applications of lime will increase with each year it is under cultivation. The additions of rock phosphate, acid phosphate and complete commercial fertilizer gave increases in the yields of both the wheat and the clover. Unfortunately the clover crop in the acid phosphate pots was very evidently abnormal and the results are not included here. The rock showed up somewhat better than the acid on the wheat crop and the commercial fertilizer likewise gave a larger effect than the acid phosphate, but smaller than the rock. On the clover, the complete commercial fertilizer proved slightly more effective than the rock phosphate. In general, definite conclusions cannot be drawn from these experiments regarding the relative merits of the two phosphorus fertilizers and the results should not be interpreted to show definitely the value of the complete commercial fertilizer as against the phosphates. Field tests are needed to show accurately the need of phosphorus on this soil, and also to determine whether the rock or the acid should be employed. These results merely serve to indicate the possibility of value from the use of phosphorus fertilizers.

In general, it appears that applications of manure are very desirable on the Webster clay loam. When this soil becomes acid in reaction, lime should be employed and there are strong indications of value from the use of phosphorus carriers. It is doubtful whether complete commercial fertilizers will prove as profitable as the phosphorus materials. Farmers are urged to test the use of rock phosphate and acid phosphate on their own soils and thus determine for their particular conditions which material would prove the most profitable.

FIELD EXPERIMENTS

The field experiments which have been started in Winnebago county have not yet been under way for a long enough period to permit of the publication of the

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results secured. Such experiments must be continued for several years before the results from them can be utilized for the drawing of conclusions. The data obtained from these experiments will be published later in a supplementary report.

There are some experiments under way, however, in adjacent counties, which have been running for several years and the results from some of these fields may be included here in order to give some idea of the character of the results which may be secured in this county later. The results of these experiments should not be interpreted too broadly, as they have not been carried on for any extended period of time, but they do serve to indicate the needs of the soils of this county and the value which may come from the application of certain fertilizing materials.

These field experiments are all planned with the idea of determining the relative value of various soil treatments and they are laid out on land which is entirely representative of the individual soil type. They are permanently located by the installation of corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of the crops to be sure that accurate results are secured. These fields include tests under the livestock and grain systems of farming, manure being applied in the former and crop residues being utilized instead of manure in the latter. Only the plots in the livestock system are included in the results given here, as there has not been opportunity for the crop residue treatments to show up very definitely yet. Other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. Limestone is used in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in the rotation, acid phosphate at the rate of 200 pounds per acre annually, and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. The plots in these experiments are 156 feet, 6 inches, by 20 feet, or one-tenth of an acre in size.

THE TRUESDALE FIELD

The results on the Truesdale field, Series I, are given in table IX. This field is located in Buena Vista county on the Carrington loam, as mapped in that county, a type which is identical with the Clarion loam of Winnebago county as far as the surface soil is concerned. The only difference between the types is that the Clarion loam contains some lime in the subsoil and, as this condition has little or no effect on the crop yields, the results of these field tests on the

TABLE IX. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY
Truesdale Field—Series I

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover tons per acre 1921
1	Check	38.9	56.5	57.2	1.40
2	Manure	44.3	57.1	57.9	1.20
3	Manure+Lime	46.4	58.1	59.2	1.60
4	Manure+Lime+Rock phosphate	54.4	58.7	64.7	2.45
5	Manure+Lime+Acid phosphate	49.6	58.7	64.9	3.30
6	Manure+Lime+Complete commercial fertilizer	49.6	58.7	64.7	3.10
7	Check	38.4	58.1	56.4	2.20

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Carrington loam may be considered to apply very closely to the Clarion loam in Winnebago county and the effects noted may be considered indicative of the needs of the Clarion loam in this county.

In this experiment a complete four-year rotation has been carried out and the effects of treatment on two corn crops, one oats crop and one clover crop are shown. Manure brought about a distinct effect on the corn in 1918 and a smaller influence on the same crop in 1919. Very little influence was noted on the oats in 1920 and none at all on the clover in 1921. The yield on the manure plot in 1921 was evidently somewhat abnormal, as a smaller yield was secured than on the check plot. The beneficial effect of lime in addition to manure is apparent on all the crops of the rotation, showing up not only on the clover but on the corn and oats also. It would seem that lime may exert a beneficial effect indirectly on the grain crops of the rotation and the value of applying lime to this soil should not be measured entirely by the effect on clover, altho the legume crop of the rotation would undoubtedly be influenced most.

Rock phosphate, acid phosphate and the complete commercial fertilizer all brought about definite increases in the crops of the rotation, except the corn crop of 1919, which was increased to only a slight extent. The clover was affected to a much larger degree than the other crops, and with this crop the acid phosphate proved superior to the rock phosphate, while the complete commercial fertilizer was somewhat less effective than the acid phosphate. On the oats and on the corn in 1920, the three materials exerted almost identical effects. On the corn in 1918, rock phosphate seemed to be somewhat superior to the other materials. Apparently phosphorus may be of value on this particular soil type and the application of phosphorus fertilizers may lead to distinct crop increases Further experiments are necessary before definite comparisons can be made between the rock phosphate and acid phosphate, but these results seem to indicate superior value for acid phosphate on clover. The complete commercial fertilizer does not seem to have any larger influence than the phosphorus carriers and in some instances shows a smaller effect. It seems unlikely, therefore, that these materials would prove as profitable as the phosphorus fertilizers, inasmuch as they are more expensive.

The results on Series II from the Truesdale field are given in table X for the years 1920 and 1921. The yield of oats in 1920 was very irregular and the clover in 1919 winter-killed. The results obtained on the corn crops in 1920 and 1921 are given here, however, as they largely confirm the conclusions reached from the results of Series I. Again the beneficial effect of manure is evidenced, def-

TABLE X. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY
Truesdale Field—Series II

Plot No.	Treatment	Corn bu. per acre 1920	Corn bu. per acre 1921
1	Check	47.5	32.8
2	Manure	57.0	39.7
3	Manure+Lime	59.0	41.8
4	Manure+Lime+Rock phosphate	61.2	38.1
5	Manure+Lime+Acid phosphate	62.1	40.1
6	Manure+Lime+Complete commercial fertilizer	64.0	44.4
7	Check	57.1	36.2

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inite increases in corn yields following the application of this material. Lime in addition to manure gave a further increase and the phosphorus carriers all showed effects except the rock phosphate in 1921, and the yield on that plot was evidently abnormal.

It seems apparent from these field experiments that manure is a particularly valuable fertilizing material for the Clarion loam and beneficial effects will be secured from its use on the various crops which may be grown. Lime should be used when the surface soil is acid and beneficial effects from this material will be noted, particularly on the clover crop of the rotation. Phosphorus fertilizers seem to be of value on this soil and tests of rock phosphate and acid phosphate on small areas are recommended. If rock phosphate or acid phosphate yields a profitable increase on a small area, then the farmer may be sure that the use of that material will prove profitable on a large area. Complete commercial fertilizers do not seem to be of any greater value than the phosphorus carriers and in some instances they have less effect on crop yields. They may be employed, however, provided comparative tests show them to be of superior value under particular conditions.

PEAT SOILS

Peat is partially rotted vegetable matter, which consists either of swamp grasses, sedges, rushes, and flags, or of sphagnum moss, the former variety being known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas, where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits of only very incomplete decomposition. Deposits of peat thus formed increase from year to year and with the long continuance of swampy conditions may become of considerable depth. When the glacier which once covered north central Iowa retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area, especially near the edges, and in these places lakes, ponds and marshes were formed because of the heavy, impervious character of the subsoil, and the formation of peat followed. It is mainly in the Wisconsin drift soil area that peat occurs in Iowa.

Winnebago county is located in this soil area and has several areas of peat, together making a total of 6,912 acres, or 2.7 percent of the total area of the county. The peat areas occur mainly in the eastern part of the county, the largest occupying what was formerly Bear lake and Rice lake. There are also rather large acreages of peat north of Lake Mills, west of Scarville in the vicinity of Thompson, and both west and east of Forest City.

A complete discussion of peat soils in Iowa and a report of certain experiments which have been carried out to determine their needs have been given elsewhere* and no extended consideration of these soils need be entered upon here.

There are two classes of Iowa peats, the shallow and the deep. The latter have been mapped by the Iowa Geological Survey and their commercial value pointed out. They are composed of fibrous, fairly dry vegetable matter, extending from 5 to 15 feet in depth, and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and

*Bulletin 157, Iowa Agricultural Experiment Station—Improving Iowa's Peat and Alkali Soils.

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the reported experiments on peat soils have dealt only with shallow peats. The suggestions and recommendations regarding the treatment of peat soils which are made in this report refer, therefore, only to the shallow peats and are not at all applicable to deep peats.

The peat in Winnebago county is generally less than three feet in thickness and only in a few localities does it extend to a depth of more than four feet. Practically all the peat soils in this county may be reclaimed and made productive by proper methods of treatment and cropping.

The analyses of numerous samples of peat soils reported in the bulletin referred to, showed that they contained not only an abundance of nitrogen and organic matter, but also considerable amounts of lime. Their phosphorus and potassium content was rather low, but these elements were abundant in the clay which forms the subsoils of practically all the shallow peats in Iowa. The character of the subsoil plays a very important part, as will be seen in the treatments which are advised for the reclamation of peat soils. On this account the heavy character of the subsoils underlying the peats in this county is emphasized.

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story counties, and these tests were considered at length in the bulletin mentioned. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination, in the amounts in which such materials are generally applied to soils. In no cases were there any profitable increases in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and the untreated soils were only such as might well occur between duplicate plots..

It is apparent from the data given in those field experiments that the shallow peats in Winnebago county do not need the addition of commercial fertilizing materials to make them productive. Altho they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be profitable. The crop seems to be able to secure a sufficient amount of these plant foods from the subsoil, which is well supplied with them. Furthermore, peat soils contain an abundance of nitrogen and organic matter and applications of manure are not advisable. Not only is it of no special value, but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria into the peat and increase the speed of decomposition. In general, manure should not be used on peat soils, but should be utilized on land in greater need of organic matter and nitrogen.

DRAINAGE AND CULTIVATION FOR PEAT SOILS

What the peats in Winnebago county need to make them productive is the physical improvement resulting from drainage, cultivation and the growing of the proper crops on them.

The drainage of peat soils is the most important step in their reclamation. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall, are essential.

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The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself, as in the latter case the compacting of the peat would bring the tile too close to the surface and relaying would be necessary. The tile should not be laid too deeply in the subsoil, as the heavy clay is impervious to the passage of water. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will permit of the ready passage of water into the drains.

Fall plowing is desirable for peat soils in order to expose the soil to the action of the frost, rain and snow during the winter and hasten the decay of the peat. Fall-plowed peats may be worked earlier in the spring; hence the seed bed may be more thoroly prepared.

Deep plowing of peat soils is also of considerable value, especially when the peat is very shallow and some of the underlying heavy clay, rich in phosphorus and potassium, may be mixed with the peat. The physical and chemical conditions in the peat are both improved materially by such a mixing and crop production is increased. Even in the case of deeper peats, where the subsoil is not reached by the plow, it is of advantage to plow to a considerable depth in order to open up the peat to the action of air and thus hasten decomposition.

Iowa peat soils which are not over 16 inches in depth should not be rolled, as such an operation may compact them too much and retard the decomposition of the peat. Where the peat is deeper than this, careful rolling may be of value in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening the decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivating the peat, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be luxuriant and interfere seriously with the production of crops.

Corn and small grain crops as a rule do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore it is not advisable to seed these crops on peat soils until several years after their reclamation, when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat to an extent which aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes, and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit of the successful growth of corn and small grain crops. When properly reclaimed, peat soils may become extremely productive and it is certainly advisable to attempt the utilization of the peat areas in Winnebago county. With proper treatment and crop growth they can be reclaimed.

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"ALKALI" SOILS

So-called "alkali" spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

There are several areas of "alkali" soils in Winnebago county and, while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots, while other crops are affected to a less extent.

The origin of these spots has been discussed in another publication. They occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough, but always in a belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in the bulletin mentioned, and more in detail in a later publication, and it is apparent from the studies which have been carried out that the salts which occur are variable. The chief constituent is calcium bicarbonate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. A variety of other salts is also common to the Iowa "alkali" soils, magnesium carbonate, nitrates, sulfates and the carbonate and bicarbonate of sodium being frequently found. The amounts of these latter salts which make up the "alkali" content of Winnebago county "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium carbonate which always occurs, may prove injurious.

The "alkali" problem in Winnebago county and in Iowa in general is therefore less serious than in the west, and reclamation is more readily accomplished.

TREATMENT FOR ALKALI SOILS

The first treatment necessary for the reclamation of "alkali" soils in Iowa is proper drainage. "Alkali" spots do not appear until after a soil is drained, but this does not mean that the drainage produces the "alkali" condition. A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thoro drainage is essential for the removal of "alkali" salts from the soil and in draining a slough or pond, lines of tile should be laid around the low area, as well as thru the center. These two lines will then run thru the area where the "alkali" is most likely to appear and the washing out of any excess of salts will be much more rapid. The lines of tile may be brought together again below the slough and, if the area is rather wide, a third line of tile thru the center of the slough may be advisable.

If tile is properly laid when a pond or slough is to be drained, the occurrence of "alkali" spots may frequently be prevented. When the "alkali" spot is fully developed, as is sometimes the case in Winnebago county, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable

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matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on "alkali" spots and should be used wherever available in sufficient amounts. In other cases, green manures or straw may serve, but where such materials are used, a small application of manure should be made along with them in order to hasten the decomposition processes, which in turn hasten the removal of the excess of salts. No other fertilizing constituents are of value in reclaiming "alkali" soils, as far as is known.. The thoro drainage of the areas and the introduction of an abundance of organic matter are the most effective methods which can be employed.

THE NEEDS OF WINNEBAGO COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

Field experiments have just been started on some of the main soil types in Winnebago county and there is no data available as yet showing the value of various fertilizer treatments. The field experiments from Buena Vista county which are included in this report are located on a type which is practically identical with the predominant soil in Winnebago county, and the results of those experiments may be considered to indicate quite definitely the results which may be secured in Winnebago county. When the experiments which are under way in this county have been carried on for a period of years, definite conclusions may be drawn regarding the most economic treatments for the various soil types. For the present the suggestions which are made regarding desirable treatments are based only on the results of the laboratory and greenhouse tests and on the field tests from Buena Vista county. No definite recommendations are made in this report which have not been tested to some extent by individual farmers and proved valuable by practical experience.

Individual farmers are urged to test the use of various fertilizing materials on their own soils and determine their value for the particular conditions. Information secured in this way may be of much practical value to the farmer and will also be of interest and value to many others, for the results will aid in the solution of the problem of fertilization of the same soil types elsewhere. Many farmers are now carrying on tests on a small scale and are finding that such tests may be very readily planned and easily carried out. The Soils Section of the Iowa Agricultural Experiment Station will aid and advise farmers who wish to conduct tests on their own farms. Until the field experiments now under way are more complete and the results conclusive, the best suggestion which can be made is that various phosphorus fertilizers be tested on small areas and in this way the farmer may determine whether or not the soil needs phosphorus and likewise determine which material is of most value. No recommendations given in this report are made except those which have been shown by practical experience to be of value and which may be put into operation under any farm conditions.

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MANURING

The soils of Winnebago county are fairly well supplied with organic matter in all cases and in some instances there is a very large amount of this material present. This is evidenced by the typical black color of many of the soils. It would not be expected, therefore, that manure would prove of as much value on the soils of this county as in the case of lighter colored, light textured types such as occur in other counties. It is surprising, however, to note the beneficial influence of farm manure even on those soils which are very well supplied with organic matter. On the more rolling uplands in the county manuring proves of large value and, in fact, there is no other fertilizing material which exerts anything like as large effects on crop growth, but even on the black level uplands, manure increases crop yields and the increases are large enough to be profitable. It seems apparent, therefore, that farm manure is a most valuable fertilizing material for use in this county and farmers should see to it that the manure produced on their farms is carefully preserved and applied to the soil in order to secure the largest crop yields, as well as to keep the soils permanently productive.

Manure exerts beneficial effects on soils because of its influence on chemical, physical and bacteriological conditions. It contains some of the essential plant food constituents, hence improves the chemical condition of the soil, and it also contains organic matter which has an important effect on the chemical condition of the soil. Many of the plant food constituents taken from the soil by the crops grown are contained in the manure, and if the manure does not undergo losses of these valuable constituents, it may return to the soil a very large portion of the plant food removed. Thus it lengthens the life of the soil, or in other words, prolongs the time until any of the essential plant food constituents become deficient. Both light and heavy soils are improved physically by the application of manure, the former being made more retentive of moisture and less open and porous and less subject to losses by leaching. Heavy soils are opened up and made less impervious and better aerated, and excessive moisture is more readily removed. This physical improvement of soils is reflected in a larger production of available plant food and may lead to a better feeding of crops. The physical effects of manure are due to its organic matter content and are the results of the effect of organic matter on soil conditions.

Manure contains enormous numbers of bacteria which bring about the production of available plant food in soils; hence, the addition of manure to soils will lead to more available plant food for crops. Not only is there greater bacterial action from the organisms introduced, but those already present in the soil are stimulated to greater activity and more available plant food is the result. On many of the soils of Winnebago county the beneficial effects of manure are undoubtedly very largely due to the bacterial factor, or in other words to the stimulation of available plant food production. Where the soils are low, poorly drained and high in organic matter, conditions are not as desirable for bacterial action as they should be and available plant food production may be low. When such soils are drained, opened up and cultivated, the addition of a small amount of manure, by merely introducing bacteria, may lead to more satis-

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factory crop growth. In general, however, the beneficial effects of manure are probably due to its chemical, physical and bacteriological effects, combined. From the standpoint of permanent fertility, it exerts probably its most important influence by keeping up the supply of the individual plant food constituents.

The value of manure as a fertilizer for general farm crops is so great that it is surprising that so little attention is paid to preserving this material and providing for its application to soils with as little loss of valuable matter as possible. If it is stored in loose piles exposed to the weather, 70 to 90 percent of its value may disappear. When this occurs, the manure will exert only a small part of the beneficial effect on crops which ordinarily would be secured. Certainly crop yields will be increased to a very much smaller extent, and the loss of the fertilizing properties of manure thru improper storage means actual money loss on the farm. The farmer who does not take care of the manure on his farm is wasting one of his most valuable assets and that waste is reducing his income from the farm. There are various ways in which manure may be stored in order to prevent losses before application, and no one method can be recommended for use under all conditions. It may be stored in a covered yard, or in a pit; it may be composted; it may merely be protected from the weather; but whatever method is employed, it is very important that the manure be kept moist and compact and prevented from losing the liquid portion thru the leaching action of rains. In some instances it may be possible to apply the manure to the soil as produced. In such cases there is no storage problem and the largest possible effects may be secured from the application of the material.

When manure is applied as produced, or is carefully stored, it is estimated that 75 to 80 percent of the plant food removed from the soil by the crop grown may be returned to the land. It is important therefore that the livestock farmer see to it that he does not waste this important fertilizer, but takes precautions that he secure full value from its use. On the average livestock farm the production of manure is insufficient to permit of any large application to all the soils of the farm. The usual application is 8 to 10 tons per acre once in a four-year rotation. Larger applications than this are sometimes made, but it is not desirable to apply more than 16 to 20 tons per acre under any conditions, for general farm crops. If large applications of manure are made to one field, the remainder of the farm may suffer. Hence it is well to arrange the applications of manure at regular intervals and in reasonable amounts, in order to keep all the soils of the farm supplied. Smaller applications than those suggested above may be made with good results on the dark-colored level upland types in this county, and on the black terrace and bottomland soils, when the latter are drained, and on such soils the larger applications are not recommended nor desirable. Especially where small grain crops are to be grown on the heavier dark-colored soils, manure should not be applied immediately preceding the small grain crop, owing to the danger of lodging. In such cases, the manure should be applied at some previous time in the rotation.

The beneficial effect of manure on all farm crops has been shown by many experiments and is evident from much practical farm experience. It is very important, therefore, that this material be utilized on the farms of Winnebago

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county as far as it is available and, if other fertilizing materials are employed, they should be used in addition to manure if economic results are to be secured. No other fertilizing materials will prove of as large value if manure is not employed. These statements apply, of course, only to the livestock farm. If farm manure is not available, then other sources of organic material must be employed.

On the grain farm some material must be chosen for use in place of farm manure and on the average livestock farm there is not sufficient farm manure to keep up the supply of organic matter and nitrogen on all the soils of the farm. In both cases, therefore, some practice must be adopted to take the place of farm manure and the use of leguminous crops as green manures is the practice which is recommended and which proves most economically desirable. Leguminous crops are the most desirable for use as green manures because of the fact that when well inoculated they possess the ability to take up nitrogen from the atmosphere and fix it in the soil, where it is available for the use of subsequent crops. Such crops may act, therefore, really as nitrogenous fertilizers. They have large value because of the organic matter which they supply to soils and it is because of this addition of organic matter that green manuring is considered the most desirable substitute for farm manuring. Non-legumes may be utilized as green manures. They add organic matter to the soil, but they do not increase its nitrogen content. When the nitrogen supply in the soil is adequate and the addition of organic matter only is needed, non-legumes may be used very profitably. In general, however, leguminous crops are much more desirable and prove much more profitable. There are many legumes which are available for use as green manures under a wide variety of conditions, so that some one may be chosen which will fit in with almost any rotation. Under grain farming conditions and, in some instances, under livestock farming systems, green manuring may be practiced profitably. It is a practice, however, which should not be followed blindly nor carelessly, as undesirable effects may result if the green crop does not decompose rapidly enough in the soil. If the soils are not sufficiently moist, green manuring may prove undesirable, owing to detrimental effects on the moisture conditions in the soil. Advice regarding the practice of green manuring under special soil conditions will be given by the Soils Section upon request.

The utilization of all crop residues, such as straw and stover, is a very important practice for keeping up the organic matter content of soils. These materials are often burned or otherwise destroyed, thus wasting material which would be valuable in keeping up the organic matter in soils. On the livestock farm such materials may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil, or they may be stored under proper conditions and allowed to decompose partially before application. It is particularly important that these materials be applied to the soils on the grain farm where there is no addition of manure, but even on the livestock farm, crop residues should be utilized in order to supplement the applications of manure. They not only add organic matter but they add much plant food and so are of large value in the maintenance of permanent fertility. Thru the proper use of crop residues and green manures, the grain farmer may keep up the organic matter content of his soils even without

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the use of farm manure and frequently the livestock farmer must depend upon these materials to supplement the farm manure which is available for distribution on his land.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of the soils of Winnebago county is not very high in any case, and in some of the types the supply is not sufficient for any large number of crops. Hence it is quite certain that phosphorus fertilizers will be needed on these soils in the near future if the most satisfactory crop yields are to be secured. There are undoubtedly conditions under which phosphorus fertilizers would prove of value in this county at the present time. Even where the total supply of phosphorus is large, applications of phosphorus fertilizers may prove profitable if they supply the element in an available form, as the production of available phosphorus is often too slow to supply the proper amount for the best crop yields. When the total amount of phosphorus in soils decreases, however, it is well known that the amount of the element in an available form decreases much more rapidly, and a low content of total phosphorus indicates definitely the need of phosphorus in an available form.

There are evidences from the greenhouse and field experiments in this county that phosphorus fertilizers may prove of value at the present time on some of the soils of the county and it may very safely be concluded that phosphorus fertilizers will be needed on all the soils of the county in the near future if their fertility is to be maintained permanently. Farmers are urged to test the need of phosphorus on their soils by the application of a phosphorus fertilizer to a small area, and if profitable crop increases are secured and it is evident that phosphorus will prove of value, then they may make applications to large areas.

There are two phosphorus fertilizers which may be employed, rock phosphate and acid phosphate. Acid phosphate is more expensive than the rock but it contains the phosphorus in an available form and the element is therefore utilizable immediately by plants. Rock phosphate on the other hand has a low rate of availability and must be applied to soils in much larger amounts. The choice between these two phosphates must be made on the basis of the relative cost of the actual application and the relative value of the crop yields secured. The field experiments now under way are testing these two materials and comparing them and eventually it is hoped that definite recommendations regarding the use of these fertilizers may be made. For the present the experimental results will not permit of a choice being made and farmers are urged to test the value of both the rock phosphate and the acid phosphate on their soils, thus ascertaining for their particular conditions which material will prove more economically desirable. It is comparatively a simple matter to test the use of phosphorus fertilizers on the farm and farmers may readily make such tests as are suggested. Directions for the carrying out of tests are given in Circular 51 of the Iowa Agricultural Experiment Station. If one of the fertilizers applied gives a profitable increase in crop yield on a small area, then that particular material may be applied to a large area with the assurance of profit. Tests of phosphorus fertilizers on Winnebago county soils are very desirable and it is hoped that many

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farmers will carry out such tests as are suggested and solve the phosphorus problem for their own conditions and at the same time aid in the solution of the problem for the whole state.

Most of the soils in the county seem to be rather well supplied with nitrogen, but the amount present is not sufficient to warrant overlooking this element in planning systems of permanent fertility. Where large crop yields are secured and drainage conditions are entirely adequate, there is a constant removal of nitrogen by leaching and by assimilation by growing plants. Hence nitrogen is being removed from soils constantly and some means must be employed to keep up the supply. The proper care and use of farm manure will aid materially in keeping up the nitrogen in soils, but this material alone is not sufficient, even on the livestock farm, where it is available for use in considerable quantities. On the grain farm some nitrogenous fertilizer must be employed, and leguminous green manure crops are the cheapest and most effective nitrogenous fertilizers which can be used. Frequently they are also important fertilizers for use on the livestock farm to supplement the manure. Every rotation should contain a legume, and if this legume is inoculated and the crop turned under in the soil, at least in part, there may be a considerable addition of nitrogen to the soil. Of course, if the legume crop is removed from the soil, the nitrogen content will not be increased. If it is to serve as a nitrogenous fertilizer, a large part of the crop must be turned under as a green manure. If only the seed of the legume is removed and the remainder of the crop is used as a green manure, much nitrogen may be added to the soil. Legume crops may often be used as catch crops and serve in this way to increase and maintain the nitrogen in the soil, as well as to build up the organic-matter content. The proper utilization of crop residues is an important means of cutting down the loss of nitrogen from soils and such materials may be considered to a certain extent as nitrogenous fertilizers. Commercial nitrogenous fertilizers may be utilized in small amounts as top dressings, but their use for general farm crops on the soils of this county cannot be recommended at the present time. If they prove of value when tested on small areas, they may be utilized, but in general leguminous green manures seem to be much cheaper and quite as satisfactory for keeping up the nitrogen content.

Earlier tests of the soils of the state have shown a large content of potassium in practically all cases. It is unlikely, therefore, that potassium fertilizers would prove of value for general farm crops. Only in soils where the production of available potassium is very low, due to improper soil conditions, would there be any possible need for adding commercial potassium carriers. If the soil is kept in the best physical condition from the standpoint of organic-matter content, and the moisture content is adequate, there is every reason to believe that sufficient potassium would be produced in an available form to supply the needs of crops for almost an indefinite period. Hence, potassium fertilizers cannot be recommended for general use on the soils of Winnebago county, but it is urged that precautions be taken to insure proper physical conditions in the soil for an adequate production of available potassium. It may be that a small application of a potassium fertilizer would be of value as a top-dressing for stimulating the early growth of some particular crop and occasionally newly drained

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land has been found to respond to the application of potassium, but in these cases it is evident that the beneficial effect is due to the fact that there is an inadequate production of available potassium.

Complete commercial fertilizers cannot be recommended at the present time for general use in this county and it is believed that phosphorus carriers will probably prove much more profitable. Nitrogen may be more cheaply supplied by the use of leguminous green manures, and potassium is rarely needed. The chief value of the complete materials is due to the phosphorus content, and as phosphorus carriers are less expensive than the complete brands, if they give as large crop increases, they are certainly more desirable. The field experiments now under way in the county include the use of complete brands along with the phosphorus carriers, and eventually it is hoped that definite comparative data regarding the relative value of these materials will be available. At the present time it can merely be suggested that farmers who are interested may test any complete brands on small areas on their own farms at the same time that they are testing phosphorus carriers and if profitable results are secured, then the complete materials may be employed on larger areas with assurance of profit and, particularly, with the assurance of greater profit than from the use of the phosphorus materials. There is no objection to the use of complete commercial fertilizers if they are profitable, but it is very important that they be compared with the phosphorus carriers in order that it may be definitely determined whether or not they should be used.

LIMING

Many of the soils of Winnebago county are well supplied with lime, so that additions of this material are not necessary at the present time and probably will not be necessary for many years. The Clarion loam, however, and the rolling phase of the same type,—the most extensive upland soils in the county,—are acid in reaction in the surface and subsurface layers and in need of lime, if the best crop growth is to be secured. The Waukesha loam, too,—a terrace type,—is acid, and applications of lime are needed on this soil for the best growth of legumes. Even tho the lower soil layers are high in lime, as is generally the case thruout the county, if the surface soil is acid, lime must be added or satisfactory crops will not be secured. Lime rarely moves upward in the soil, while, on the other hand, it is constantly being washed out of the soil in the drainage water, so that there is a continual reduction in the amount of lime present in the soil. There is some utilization by crops, also, and in some instances the removal of lime from soils in various ways may very quickly cause the soil to become acid in reaction. Thus, even tho some of the soils in the county are at present apparently well supplied with lime, they will eventually need applications of this material, particularly if they have not been adequately drained and later are brought under satisfactory drainage conditions.

It is apparent that much of the upland in the county must receive lime at the present time or in the very near future, if the best growth of crops, and particularly of legumes, is to be secured. These soils should be tested at regular intervals and lime applied as shown to be necessary. The figures given in the tables

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earlier in this report are merely indicative of the needs of the individual soil types and should not be taken to show definitely how much lime should be applied to the particular soil. Soils vary widely in lime requirement and even the same soil type may show a variable acidity. Hence, before lime is added to any soil, that particular soil should be tested in order that the proper amount of lime may be applied. Farmers may test their own soils for acidity or they may send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they may be certain that they are making a proper application of lime and that they are putting the soil in the best condition for crop growth. Furthermore, it should not be considered sufficient to test soils once and apply lime at that time only. The gradual removal of lime from the soil which has been mentioned, makes it necessary that soils be tested at regular intervals to determine the need of supplying this material. It is generally believed that if the soil is tested once in a four-year rotation, lime may be applied in a sufficient amount to last during the four-year period. This test should be made and lime applied preceding the clover crop or other legume crop of the rotation. This is necessary, as clover and other legumes are most sensitive to a lack of lime and larger yields of these crops are always secured on limed soils. Other crops of the rotation may show some effect from the use of lime and occasionally corn or oats may be increased by the use of this material. In general, however, the value of lime is evidenced mainly on the legume crop of the rotation.

Many tests under farm conditions have shown the beneficial effects of liming and the experiments reported in the preceding pages emphasize the value of using lime on acid soils in this county. Even when the clover crop alone is considered, the use of lime is a most profitable practice. If the indirect effects on corn and small grains are taken into account, the profit from the use of lime will be much greater. The value of the increased crop yields secured much more than offsets the expense involved in the application. The farmers of Winnebago county should see to it that their upland soils are tested and lime is applied as needed if they expect to secure the most satisfactory yields of legumes. Furthermore they should test their soils at regular intervals to keep up the supply of lime if the soils are to be kept permanently fertile and crop yields are to continue satisfactory. Further information regarding the use of lime on soils, loss by leaching, and sources from which lime may be secured are given in Bulletin 151 and Circular 58, of the Iowa Agricultural Experiment Station.

DRAINAGE

Many of the soils of Winnebago county are inadequately drained, as has been noted earlier in this report. The drainage map of the county shows definitely that the natural drainage system of the county is not satisfactory and the installation of tile and drainage ditches is necessary if the soils of the county are to be made properly productive. The Webster clay loam of the upland, the Fargo silt loam of the second bottoms and all the bottomland types are in need of drainage, if they are to be made properly productive. They are naturally fertile soils, but under the poor drainage conditions which are characteristic of the

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types, crop yields are low and the first treatment needed is the removal of the excess moisture. In some areas of the typical Clarion loam on the upland, too, the drainage is not entirely adequate, especially the areas adjacent to the Webster soils. Here, also, the installation of tile is necessary.

Drainage ditches have been established in the county and considerable tiling has been done, resulting in greatly increased crop yields. Even altho the expense of draining is considerable, it is well warranted by the results secured. There is no other treatment which can take the place of drainage, and no method of fertilization will prove profitable until drainage has been effected. In general, it may be said that wherever the soils of the county are low and poorly drained, the use of tile is a necessary operation, in fact, the first treatment needed to make the soils properly productive. There are still extensive areas in the county that may be made to produce large crops if they are tiled out and where there are no natural outlets for the tile, it may be necessary to install drainage ditches.

THE ROTATION OF CROPS

The continuous growing of any one crop rapidly reduces the fertility of soils and it is very important and even necessary that a rotation of crops be practiced on all soils, if they are to continue to be satisfactorily productive. Even if the particular crop which is grown is of considerable value, the income from the land over a period of years will be greater if a rotation is practiced. The gradually decreasing yields under continuous cropping reduces the income from land to such an extent that even less valuable crops in the rotation will be worth more than the money crop and if the money crop is rotated with other crops, the yields will not be reduced and consequently the total value of the crops of the rotation will be greater. There are many rotations which may be practiced, and no one rotation can be recommended for all conditions. No special studies of crop rotations have been made in Winnebago county, but there are a few rotations which have proved of general value thruout the state and these are suggested. Almost any modification of these rotations or, in fact, any rotation may be utilized, provided a legume is included. The following are important rotations in use in the state:

I. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.)
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy.)
Fourth Year—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain.)

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Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur. Hence, it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will, of course, wash over it and much of the soil may be carried away in this manner, to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion, while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is generally the cause of erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues, if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil is exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but it is less harmful and is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is costly and inconvenient.

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Erosion may occur to a considerable extent in Winnebago county in the rolling phase Clarion loam and also in the steep phase Clarion loam. Gullies are formed many times in the more strongly rolling areas of the former type, and there is much washing away of the surface soil over the entire type. It is very important that means be taken to protect this soil from serious injury thru erosion, and on the steep phase Clarion it will probably be most desirable to keep the type in permanent pasture where it is too steep to be satisfactorily farmed.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows," to small gullies, to large gullies, to bottoms, and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope, or even at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is usually customary to "plow in" the small gullies that result from these dead furrows and, in level areas where the soil is deep, this "plowing in" process may be effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside, at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES.

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the

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gully. Brush is intertwined between the posts, straw is well tramped down behind them, and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch, but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is desirable before any success can be had in filling small or large gullies.

"Staking in." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of "dead furrow" gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case, consists in using the brush without stakes. The brush is cut so that a heavy branch, pointing downward, is left near the top. This branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems, and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed upstream instead of downstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brush piles may be installed up the course of the gully and, with the regular repair of washouts or undercuttings, may prove very effective.

A modification of this system of "staking in" which is being used with success in some sections consists in covering the bottom and sides of the ditch with straw for a distance of from four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend, of course, upon the size of the gully. These posts should be set into the ground and spaced about four feet apart, being arranged in a V-shape, with the point down stream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise, too large amounts of water may

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accumulate above the dam and wash it out. In general, it may be said that when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided, the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or run-off to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides, to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later to seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey Dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" has been applied, hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made, of sewer tile with tightly cemented joints, and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory methods of filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams, the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory, and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish, even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven-wire, especially in connection with brush or rubbish, has sometimes proved satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" sys-

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tem. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and, for quick results, sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water-absorbing power of the soil, decreasing the tendency toward erosion. Catch wells properly located over the surface, consisting of depressions or holes filled with coarse gravel and connected with the tile, help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES.

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS.

Erosion frequently occurs in bottomlands, and where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in any community and, while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows, which extend up the drainage channels. While the method has some good features,

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it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general, it may be said that in pastures, bottomlands and gulches the presence of trees may be effective in controlling erosion, but a row of trees across cultivated land, or even extending out into it, cannot be recommended.

HILLSIDE EROSION.

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed, if farm manure is not available in sufficient amounts. Crop residues, such as straw and corn stalks, may also be turned under in soils to increase their organic-matter content. In general, it may be said that all means which may be employed to increase the organic-matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years, is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable for use in such locations. The root system of these crops holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and has proved very satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall-plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion, as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil will be reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

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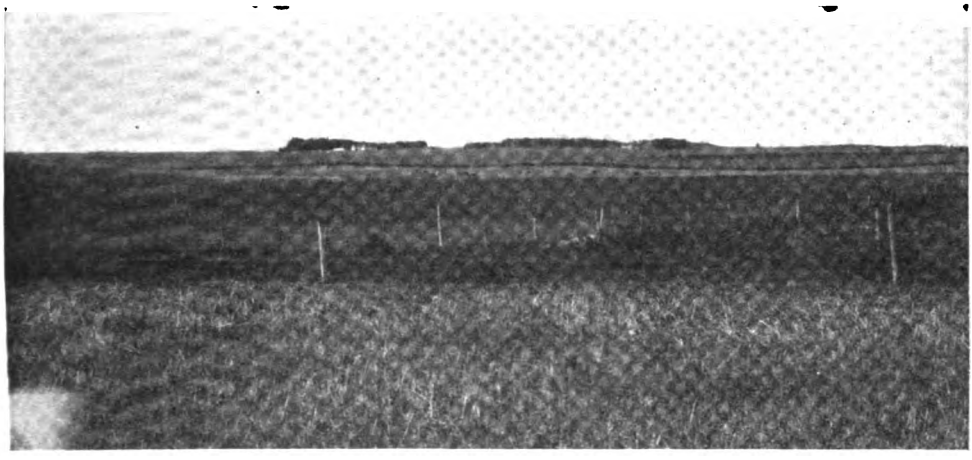

Fig. 4. Typical topography of Clarion loam in Winnebago county.

INDIVIDUAL SOIL TYPES IN WINNEBAGO COUNTY*

There are five soil types in Winnebago county and these, together with two phases of the Clarion loam and areas of muck, peat and meadow, make a total of ten separate soil areas. These are divided into three large groups, according to their origin and location, known as drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are two drift soils in the county, classified in the Clarion and Webster series. There are also two phases of the Clarion loam, making four drift soil areas. The total area covered by these drift soils amounts to 83.9 percent of the total area of the county.

CLARION LOAM (138)

The Clarion loam is the most extensive soil type in the county, as well as the largest drift soil, covering in its typical development 46.0 percent of the total area. It occurs on the uplands in all parts of the county, being developed to the largest extent in the western townships. Large areas of the type are found, however, thruout the eastern and central portions of the county, associated with the rolling phase Clarion loam on the uplands.

The surface soil of the Clarion loam is a black friable fine textured loam or silt loam, extending to an average depth of about six inches. From this point to a depth of about 20 inches there is a black or very dark brownish-black clay loam which gradually changes to a brown or yellowish-brown clay loam in the lower subsoil. The typical buff colored or gray calcareous material of the Clarion series frequently occurs within the three-foot section, but there are many instances where it appears only at greater depths. In fact, the depth to which this calcareous layer occurs is extremely variable and even within

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

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comparatively small areas the calcareous material may appear in the three-foot section only in spots. The surface soil and subsurface soil of the type are quite generally acid in reaction and in some cases the subsoil may also show acidity, depending, of course, upon the occurrence or non-occurrence of the calcareous layer in the three-foot depth.

There is a variation of the typical Clarion where forest growth has affected the soil condition to some extent. In many instances this forest growth did not occupy the soil long enough to modify to any large extent the organic conditions and the surface soil is very similar to that of the typical prairie upland of the Clarion loam. In some areas, however, the effect of forest growth has changed somewhat the soil conditions and the amount of organic matter is decreased. Just below the surface soil a dull gray friable soil with thin streaks and specks of light gray has developed. The material often has an ashy feel and is very friable. This layer usually occurs between the depths of 10 and 20 inches and below it the characteristic brown clay loam of the subsoil occurs. These areas of forested soil are too small to be separated from the typical Clarion and are not shown on the map.

In topography the Clarion loam is undulating to gently rolling. The surface drainage in general is good, but there are some local depressions and sloughs included in the type, where drainage is poor. In the areas adjacent to the Webster clay loam, drainage is generally inadequate and tiling is needed. There are areas showing slight elevations, low mounds and ridges, and here the type approaches the rolling phase. In these areas there may be some gravel, sand or stones, but the subsoil is generally a loam and rarely a sandy or gravelly loam. Boulders occur thruout the soil, but not to any large extent.

Most of the Clarion loam is in cultivation and general farm crops are grown. Corn yields 40 to 50 bushels per acre on the average and, under favorable conditions, 60 to 70 bushels per acre may be secured. Yields of oats range from 40 to 80 bushels per acre, with an average of about 60 bushels on well-managed land. Barley is grown to some extent on this soil, which is also adapted to the growing of wheat. Clover is grown only to a small extent, altho it is

Fig. 5. Stock raising is practiced to some extent on the Clarion loam.

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becoming more common to include this crop in the rotation. Small acreages near Forest City are utilized for fruit growing, and potatoes and garden vegetables grow well.

The Clarion loam is naturally a productive soil and crop yields may be satisfactory under favorable seasonal conditions. In many instances the type is in need of artificial drainage and tiling would prove of value. Applications of farm manure always prove beneficial, bringing about larger increases in yields of general farm crops. The surface soil of the type is acid and in need of lime, if the best growth of legumes is to be secured. Phosphorus fertilizers will be needed in the future and may prove of value in some cases at the present time. Experiments referred to earlier in this report show a large value from the use of manure on this soil and indicate the value from liming and the application of phosphorus. Much farm experience confirms the conclusions reached in regard to applications of farm manure. If this material is not available for use on the soil, it may be very desirable to employ a leguminous crop as a green manure. Farmers are urged to test the need of phosphorus on their soil and also the relative value of rock phosphate and acid phosphate. If these materials give profitable crop increases on small areas, they may be used profitably on larger areas.

CLARION LOAM (ROLLING PHASE) (150)

The rolling phase of the Clarion loam is the second largest soil in the county, as well as the second largest drift soil, covering 26.9 percent of the total area. It occurs most extensively in the eastern part of the county, covering large portions of the upland in the eastern half. It is associated mainly with the typical Clarion, but is spotted with areas of muck, peat, and Webster clay loam. A few small areas of the type are found in the western townships, but in this part of the county the type is very minor.

The surface soil is a very dark brown to black loam, containing some sand and a little gravel, and varying in depth from 5 to 6 inches on slopes, to 12 to 15 inches on the more nearly level areas. The subsoil is a dark brown crumbly loam or clay loam, becoming somewhat lighter in color at the lower depths. Below 20 to 24 inches it is usually a yellowish-brown clay loam, changing to a buff colored calcareous drift material just below the three-foot section. There are some local areas where the calcareous material occurs in the three-foot section. On the steeper areas and on the tops of mound-like areas, there is usually much stony material, consisting of gravel and small boulders, and the soil may be gravelly or a coarse sandy loam.

Near Lake Mills the phase varies somewhat from the typical description. In this locality it is a dark brown coarse-textured loam or sandy loam to a depth of 6 inches. From this point to 18 or 19 inches, the material is a yellowish-brown coarse-textured loam or clay loam. The lower subsoil is usually a sandy loam, changing with increasing depth to loose sand or gravel. The lighter-textured areas occur on the local elevations, while the heavier soil is found in the depressions and the gravelly layer may be below the three-foot section. On the higher points the drainage may be excessive, owing to the loose sand or gravel in the subsoil, but in the depressions the drainage may not be

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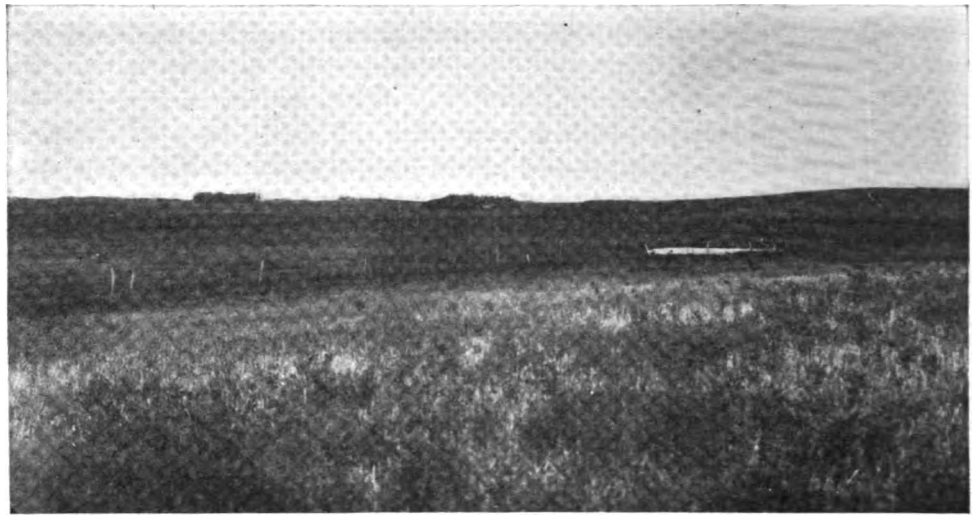

Fig. 6. Clarion loam, merging into the rolling phase in the background.

entirely adequate. This variation from the typical phase is found in some areas near Turtle Lake, five miles south of Lake Mills, but these areas are small.

In the areas east of Forest City the soil is somewhat stony and ranges in texture from a sandy loam to loam. As a rule the subsoil is a yellowish-brown clay loam, with the gravel occurring in pockets or spots. Some of the small, narrow areas near muck beds are low ridges of sandy, gravelly drift material, with varying surface conditions. The rougher areas have a scattering growth of bur oak and are in pasture, but nearly all of the areas are tillable.

The topography of the rolling phase of the Clarion loam varies from strongly rolling to hilly. In the central and western part of the county, the areas of this phase are ridges, which rise above the general level of the surrounding country. The areas near Coon Grove and to the north are quite hilly. The small areas on the borders of the muck are sandy, stony ridges. The areas between Scarville and Leland are generally high rolling ridges, the topography becoming more strongly rolling as the southern county boundary is approached. East of Lime creek the phase is less strongly rolling, but in small areas northeast of Lake Mills and near the old lake beds further south, there are sharp slopes, narrow ridges and many mound-like elevations. The roughest areas occur a few miles east of Forest City, forming the northern slopes of Pilot Knob.

The rougher areas of the phase are partly covered with brush and small timber and are generally used for pasture. Probably around 90 percent of the type is in cultivation and general farm crops are grown. The yields of corn, oats and other general farm crops are very much the same as on the typical Clarion loam. The yields of corn on the rolling phase are somewhat higher in seasons of heavy rainfall, but in normal seasons the yields are better on the typical Clarion. The large, later-maturing oats prove more satisfactory on this phase than on the typical loam. Variations in case of other grain crops are of little significance. Timothy and clover do well and bluegrass makes a very satisfactory growth on this soil. Average yields of general farm crops on most of this phase are quite satisfactory.

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In many of the small areas bordering muck, where the type occurs in sandy, stony ridges, crop production is very low, and on the upper part of the areas near Forest City the soil is more suited for use as pasture. The soil is not strikingly deficient in plant food constituents, but when used for cultivated crops it will respond to applications of farm manure, which should be used in liberal amounts. It is acid in the surface layers and lime should be applied. Phosphorus fertilizers will undoubtedly prove of value, also, in some cases. In a few minor areas, drainage is needed, but in general the type is well drained and in places may be excessively drained. The addition of organic matter is particularly necessary where the surface soil is shallow and the sandy and gravelly subsoil approaches the surface. There may be considerable washing or gullying of the type in the strongly rolling areas, and in some cases it would be most desirable to keep the soil in hay or pasture. In general, however, it may be cultivated and serious injury from washing may be prevented by building up the organic matter content thru the use of farm manure or leguminous green manure crops and taking other precautions to prevent the washing away of the surface soil.

CLARION LOAM (STEEP PHASE) (151)

This is a very minor type in the county, covering only 0.3 percent of the total area. It occurs in a few small areas north of Lake Mills and in scattered areas in other parts of the county, chiefly, however, in the eastern part, in association with the rolling phase Clarion.

The soil is a yellowish-brown clay loam, with a thin layer of darker soil on the crests of ridges and on the more gradual slopes. In most cases the surface is more or less stony and pockets of gravel are of common occurrence. Highly calcareous glacial material is often exposed at the surface. The narrow areas of this type, occurring along streams and lake beds, are steep, untillable slopes, and a few areas at other points are local elevations which are usually stony and unsuitable for cultivated crops. Only a few small areas are cultivated, and most of the phase is utilizable only as pasture land. Much of the larger areas north of Lake Mills are ridges covered in part with a growth of oak.

WEBSTER CLAY LOAM (56)

The Webster clay loam is the second largest soil type in the county, covering 10.7 percent of the total area. It occurs in all parts of the county, the largest areas being found in Grant township in the southwestern part of the county. Irregular areas, some rather considerable in size, occur in other parts of the county, chiefly in the central and western portions. The areas in the eastern part are relatively small and unimportant. The smaller areas in the northern and central parts of the county are quite variable, including small spots of Clarion loam which cannot be mapped out, and also small muck beds which cannot be shown separately. Occasionally swamp symbols in the areas of Webster clay loam will denote a mucky condition.

The surface soil of the Webster clay loam is a black mellow silty clay, containing a little coarse sand and a few pebbles, and extending only a few inches in depth. The soil then becomes a slightly compact silty clay loam or in some cases a sticky silty clay. Below 18 inches the color changes to a dull grayish-

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black, or very dark drab and at lower depths it becomes a light drab, slightly mottled with yellow iron stains. The light-colored lower subsoil is generally a sticky silty clay, but occasionally it may contain considerable sand, gravel and small stones. The surface soil is somewhat variable, particularly in the northwestern and central parts of the county, in some places having a shallow covering of muck and in others being somewhat lighter in texture and resembling the Clarion loam. The lower subsoil is high in lime, and in many cases the large lime content extends up thru the surface soils. The type is level to depressed in topography and drainage is necessary for satisfactory crop production. Tiling is very effective in reclaiming areas of this type and it is usually the first treatment needed to insure satisfactory crop growth.

General farm crops are grown on the Webster clay loam, practically all of the type being under cultivation. Some areas have not been cultivated, owing to inadequate drainage, but the installation of tile will permit of the growing of general farm crops. Corn is grown most extensively and in favorable seasons yields of 60 to 70 bushels per acre are secured. Insufficient drainage and the occurrence of "alkali" spots reduce crop yields to some extent. Average yields of oats range from 60 to 70 bushels per acre in favorable seasons, the short-strawed early varieties being most desirable for use on this soil. If the season is wet, the crop may suffer from lodging. Wheat and barley give good returns in average years and clover and timothy mixed is the most common hay crop, usually giving heavy yields. Red clover alone might be grown very satisfactorily, and alfalfa would prove a valuable crop when drainage is established.

This soil is a highly productive one and, when adequate drainage is insured, crop yields are very satisfactory. Small applications of manure might be of value on newly drained areas, and where "alkali" spots occur, large additions of fresh horse manure are recommended to aid in removing the "alkali" condition. The soil is usually high in lime content, but as it is better drained and brought

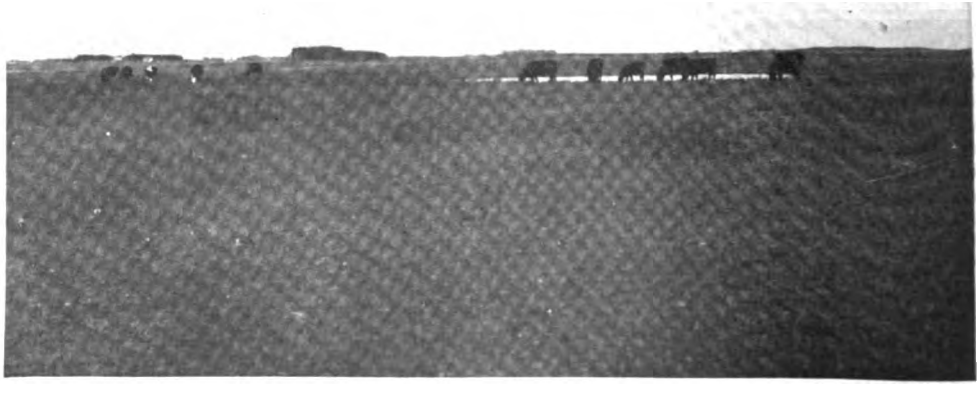

Fig. 7. Webster clay loam, Winnebago county.

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under cultivation, the surface soil will become deficient in lime. Phosphorus fertilizers might be of value in some instances now, but these materials should not be employed until they are tested. They will be needed, however, in the future.

TERRACE TYPES.

There are two terrace soils in the county, classified in the Waukesha and Fargo series. They are of minor importance, together covering only 2.5 percent of the total area.

WAUKESHA LOAM (60)

The Waukesha loam is the larger of the terrace types, covering 1.7 percent of the total area of the county. It occurs chiefly along Lime creek, the larger areas being found west of Forest City and east and north of Scarville. There are a few small areas along Blue Earth creek in the western part of the county and one area southwest of Scarville.

The surface soil of the type is a dark brown coarse-textured loam or sandy loam. At a depth of 8 to 10 inches it changes to a brown loam and the lower subsoil is a coarse loamy sand, grading at about 40 inches into coarse sand and gravel. In some areas the soil may be a clay loam and the lower subsoil a sticky, sandy, gravelly clay. Along the base of the uplands the type is usually a loam, with a heavy brown or yellowish-brown clay loam subsoil. In some places there are small muck beds, and in depressed or flat areas the type passes into Fargo silt loam. These variations occur in some of the areas northwest of Forest City and in the areas east of Scarville. In nearly all the areas along Lime creek, there are low, mound-like elevations where the soil is a sandy loam, with a rather coarse sand or gravel at a depth of 20 to 30 inches. In the western part of the county the areas are quite variable, some of them being brown loams with gravel at a depth of 4 to 5 feet, others being dark-colored heavy loam and some light in color and with sand and gravel rather close to the surface.

The topography of the Waukesha loam is generally undulating to gently rolling, the lighter variations of the type occurring as low ridges, while the heavier, darker-colored areas are quite level. The soil is well drained and in some places the drainage is excessive and the type is drouthy. This is true in many of the areas along Lime creek.

The Waukesha loam is practically all under cultivation and general farm crops are produced. Corn, oats, and wheat give satisfactory yields. The lighter variations of the type prove less desirable for general farm crops. Garden crops are grown to some extent and do well on this soil. Potatoes make large yields, and sorghum does well.

Crop yields may be increased to a considerable extent on this soil by proper soil treatment. It is chiefly in need of organic matter, and liberal applications of farm manure would be of much value, particularly on the lighter-colored and lighter-textured areas. Leguminous green manure crops would be of value in addition to manure, or in place of manure. The soil is acid and in need of lime. The phosphorus supply is insufficient for any considerable number of

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crops and phosphorus fertilizers will need to be added in some form in the near future, and may be of value in some cases at the present time.

FARGO SILT LOAM (152)

The Fargo silt loam is a minor type in the county, covering only 0.8 percent of the total area. It occurs in small areas along Lime creek, chiefly northwest of Forest City and northeast of Scarville, the areas being associated with the Waukesha loam on the terraces.

In the areas near Scarville, the soil is a heavy black silty loam, overlying a black silty clay, sometimes quite sticky. The lower subsoil in these areas varies from a light-colored sticky silty clay to a rather loose sandy loam. In the areas northwest of Forest City the soil is a black loam to silty clay loam, the loam texture prevailing adjacent to the Waukesha. In topography this type is level to depressed and drainage is inadequate. The sandy or gravelly material may occur at a depth of several feet, but the texture of the soil prevents adequate removal of surface moisture. In wet seasons water may stand on the surface of the soil for long periods and tiling is very necessary.

Most of the areas west of Forest City along Twister Branch are cultivated and large crops of corn, oats and barley are secured. Timothy and clover also do well. In the undrained areas, or the areas where drainage is not adequate, the land is used for pasture or for the production of hay.

This soil is particularly in need of drainage if it is to be made productive, and when this is accomplished large crop yields may be secured. A small application of organic matter might aid on newly drained areas. "Alkali" spots occur occasionally after drainage is accomplished, and in such cases large amounts of manure should be applied. The soil is well supplied with lime. It will eventually require additions of phosphorus fertilizers, but at present these will probably not be needed.

SWAMP AND BOTTOMLAND SOILS.

There are four areas of swamp and bottomland soils in the county, covering a total of 13.6 percent of the total area of the county. There is one soil type of the Lamoure series, and areas of muck, peat and meadow.

MUCK (21A)

There is a rather considerable area of muck in the county, covering 5.2 percent of the total area. It occurs in numerous small areas in all parts of the county. The largest area is found northeast of Thompson, and other rather extensive areas occur southwest of Scarville, east and southeast of Amund and in the vicinity of Lake Mills. Muck consists of a black, finely divided material produced by the slow decomposition of plant remains under water. There is some admixture with mineral matter, and a large number of shells, consisting of carbonate of lime, occur.

The surface material is very loose and porous and in most instances shallow in depth. The subsoil is generally a clay, a fact which is of considerable importance in the reclamation of muck areas. Deep plowing and the mixing of this clay subsoil with the very fine surface material provides improved physical

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conditions for crop growth and also supplies plant food, particularly potassium, in which muck is deficient.

Muck represents a period of change from the original peat into soil. It takes less time, therefore, to make muck productive or, in other words, to make it into soil, than it does in the case of peat, but the same treatments are needed in both instances. Drainage is of major importance, and when this is entirely adequate, muck will be changed into a good, productive soil in a comparatively short time. The same recommendations which were made regarding peat soils very largely hold true for muck areas. If drainage is made adequate, the soils will be benefited by fall plowing, and deep plowing and the frequent cultivation of such areas is valuable. Corn and small grains will not do well on these areas when newly drained, and a mixture of timothy and alsike clover is recommended. Vegetables produce satisfactory crops and onions, celery, tomatoes and potatoes have all been grown with excellent results. Cabbages, beets, turnips and other crops might also prove of value. After a few years of such a system of cropping, corn and small grains may be grown successfully.

LAMOURE SILT LOAM (153)

The Lamoure silt loam is one of the most important bottomland soils in the county, covering 5.2 percent of the total area. It occurs along the natural and artificial drainageways in the county, considerable areas being found along Lime creek, Pike's Run, Buffalo creek, North Fork Buffalo creek, Blue Earth creek, Beaver creek, Bear creek, and the various ditches which have been installed in the county. Many additional areas, some very small in size, occur in all parts of the county in the depressed, poorly-drained spots.

The surface soil of the Lamoure silt loam consists of 6 to 8 inches of a black, crumbly or rather spongy silt loam, which changes at lower depths to a sticky, silty clay, a little more compact than the surface soil. The lower part of the three-foot section is usually a sticky silty clay, with very little gravel or sand. In places it is a clay loam, or it may consist of a mixture of gravel and stones in a sticky, clayey mass. In many of the areas, spots of muck are included

Fig. 8. Peat and muck in bed of Rice lake.

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which are too small to be separated, and where the type adjoins muck or peat areas, there is no well defined boundary line. The surface soil as a rule is high in lime content and in practically all cases the soil is rich in this material thru the three-foot section. There is some variation in the character and depth of the surface soil, in different localities, but these variations are minor in significance. In some cases the subsurface is a stiff, waxy clay and the subsoil is extremely variable, as has been indicated.

This soil is flat in topography and all of it along the natural drainageways is subject to overflow, and drainage is poor. In the areas along the artificial drainage channels and in the depressions in uplands, drainage may be more readily accomplished and cultivated crops may be grown. Much of the type is now used for hay or pasture and the areas along the various creeks of the county are utilized only for hay or pasture. When well drained, the type may be very productive and will produce as large yields of crops as the Webster clay loam; in fact, it is adapted to the same crops.

PEAT (21)

The occurrence of peat in Winnebago county has been mentioned earlier in this report and suggestions regarding the best treatments have been made. This material need not be discussed further at this point.

MEADOW (20)

There is a small area of meadow in the county, amounting to 0.5 percent of the total area. It occurs along Lime creek and includes an area which is but 2 to 3 feet higher than the average level of the water in the creek. The subsoil is almost constantly saturated and slight depressions are marshy. In the better locations the soil is often practically the same as Lamoure silt loam. In some of the marshy areas it is a mixture of muck and silt. There are areas where the surface consists of a series of hummocks, 2 to 3 feet across.

There is no tree growth on this soil, except an occasional willow. In the lower areas the vegetation consists chiefly of coarse water-loving grasses and sedges. Bluegrass grows to some extent on the hummocky areas and in general on the soil where it is not too wet. The black, mucky surface deposits rest upon beds of gravel. The material going to make up meadow is so extremely variable that it cannot be mapped as a soil type and must be considered as a mixture of various materials changing in composition with every flood. The land may be used for pasturage and hay, and some of it might be rendered tillable if it were protected from overflow and well drained.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

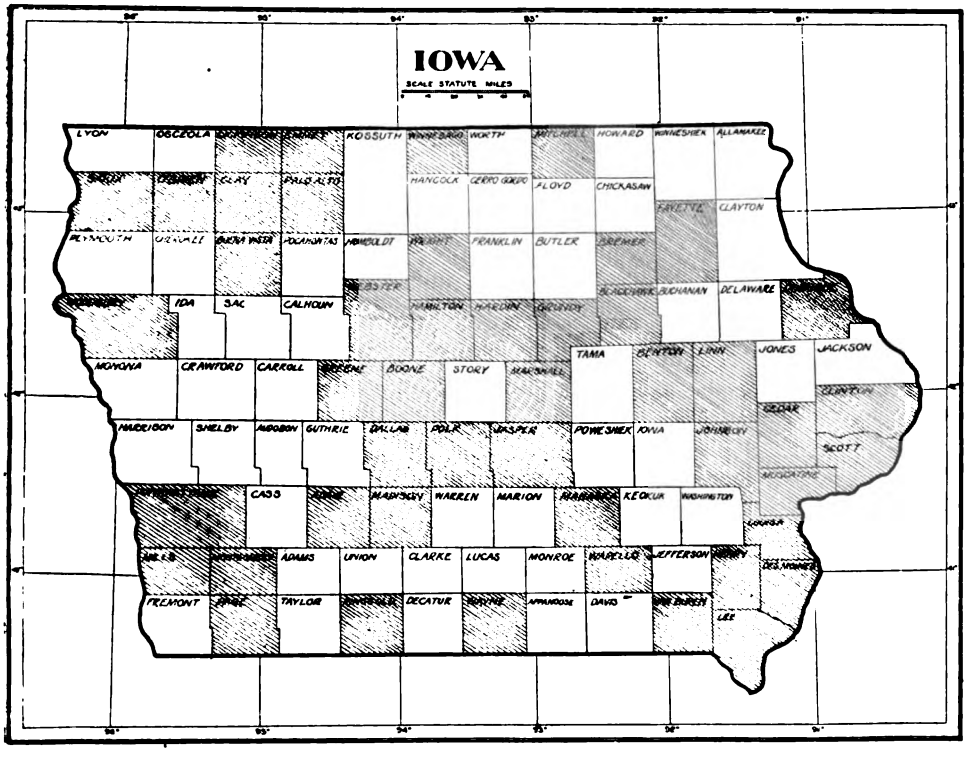

Fig. 9. Map of Iowa showing the counties surveyed.

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The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accummulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavail-*

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able. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

*Bulletin 150, Iowa Agricultural Experiment Station.

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Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between

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two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important

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in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are

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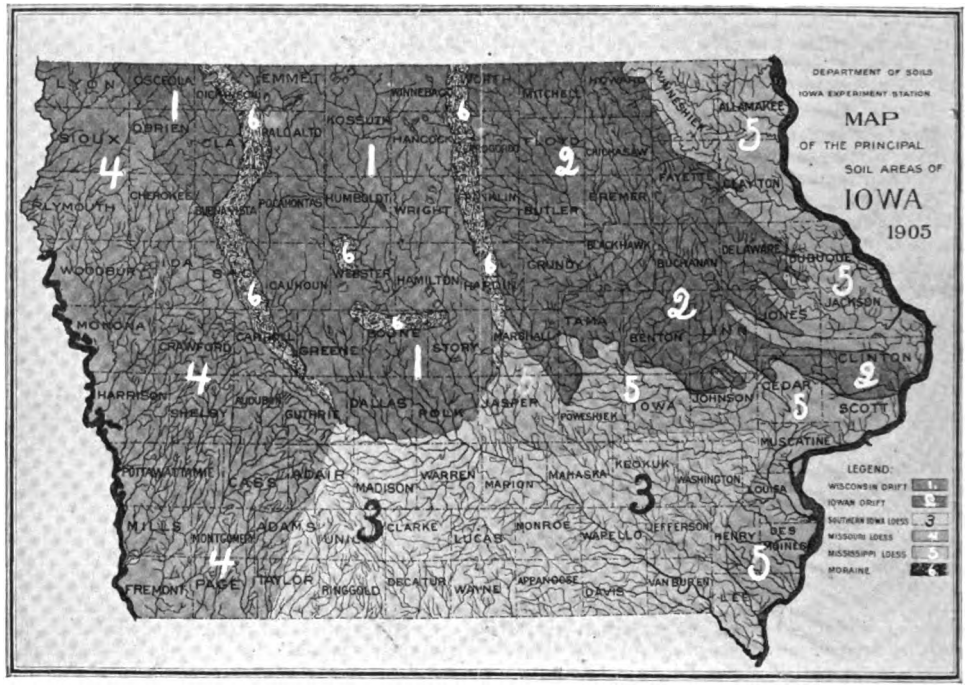

Fig. 10. Map showing the principal soil areas in Iowa

somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

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The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture of porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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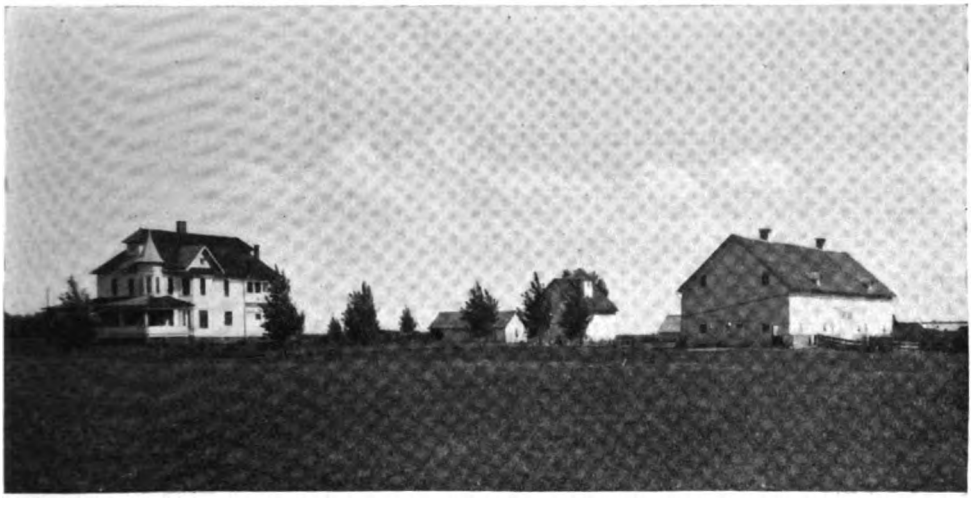
June, 1922 Soil Survey Report No. 24

SOIL SURVEY OF IOWA

Report No. 24—POLK COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, G. E. Corson and C. J. Meister



A fine farm home in Polk county

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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POLK COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, G. E. Corson and C. J. Meister

Polk county is located in south central Iowa, in the fourth tier of counties north of the Missouri state line, the sixth county east of the Missouri river and the seventh county west of the Mississippi river. It is partly in the southern Iowa loess and partly in the Wisconsin drift soil area and hence its upland soils are made up of loess and drift, the drift types occurring to a very much larger extent than do the loess soils.

The total area of the county is 582 square miles or 372,480 acres. Of this area 316,411 acres, or 84.9 percent, is in farm land. The total number of farms is 2,650 and their average size, 119 acres.

The following figures, taken from the Iowa Yearbook of Agriculture for 1920, show the utilization of the farm land of the county:

Acreage in general farm crops	213,679
Acreage in pasture	79,360
Acreage in farm buildings, feedlots and public highways	13,674
Acreage in waste land	7,311
Acreage in crops not otherwise listed	1,604

The type of agriculture practiced in Polk county at the present time consists mainly of general farming or a combination of grain farming and stock raising. Dairying and the feeding of beef cattle, however, are gradually becoming more popular. A large part of the grain produced in the county is fed on the farms and the livestock industry is gradually increasing. Polk county's agricultural income is derived from the sale of livestock, wheat, the surplus corn and other general farm crops. In the northeastern part of the county and in the vicinity of Grimes, shipping in livestock for feeding is quite common. Near Des Moines truck farming and a combination of truck farming and fruit farming are practiced to some extent. However, general farm crops are grown on the most of the farm land of the county.

There is a rather large area of waste land in the county which in many cases may be reclaimed and made productive. The methods of bringing such land under cultivation are varied and depend upon the particular condition which causes the infertility. No general recommendations can be given for the reclamation of these areas, but some method may be selected which will take care of the particular infertile condition. Special treatments which will prove profitable for individual soil conditions will be given later in this report. Advice regarding treatments most desirable in special cases may be obtained from the Soils Section of the Iowa Agricultural Experiment Station upon request.

THE FARM CROPS GROWN IN POLK COUNTY

The general farm crops grown in Polk county in the order of their importance are: Corn, oats, wheat, hay, potatoes, alfalfa, rye and barley. The average yields and value of these crops grown in the county are given in table I.

*See Soil Survey Report of Polk County, Iowa, by E. H. Smies of the U. S. Department of Agriculture and Geo. E. Corson and Chas. J. Meister of the Iowa Agricultural Experiment Station.

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TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN POLK COUNTY, IOWA

Crop	Acres	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	117,500	37.10	50.0	5,875,000	$0.47	$2,760,250
Oats	48,500	15.30	39.0	1,891,500	0.36	680,940
Winter wheat	15,700	4.90	23.0	361,100	1.41	509,151
Spring wheat	10,000	3.10	13.0	130,000	1.35	175,500
Barley	100	0.03	33.0	3,300	0.63	2,079
Rye	820	0.22	15.0	12,300	1.17	14,391
Hay (tame)	17,430	5.50	1.3	22,660	16.24	367,998
Hay (wild)	2,490	0.78	1.2	2,988	12.69	37,907
Alfalfa	600	0.18	2.3	1,380	19.23	26,537
Potatoes	539	0.17	89.0	47,971	1.22	58,524
Pasture	79,360	25.00	....	.....	....	.....

Corn is the most important crop in the county, both in acreage and value. It is grown in all parts of the county and the average yield amounts to 50 bushels per acre. Most of the corn produced is from home grown seed and probably 70 percent is Reid's Yellow Dent. Boone County White is grown quite extensively in the county. A large part of the corn produced, estimated at around 65 percent, is fed to livestock on the farms. About 15 percent is sold to other farms for feeding purposes, and 20 percent is disposed of at local markets or shipped to outside markets, generally Chicago. The corn yields of the county are in general quite satisfactory. The dark colored upland soils and the better drained heavy bottomland soils which are protected from overflow frequently give very large yields. It will be noted that the average yield for the county is considerably higher than that for many Iowa counties.

Oats is the second crop in the county in acreage and value and average yields of 39 bushels per acre are secured. About 60 percent of the oat crop is made up of Silvermine and Iowa 103. Approximately 10 percent is composed of Kherson and Iowa 105 and Green Russian, White Russian and some other varieties are grown to some extent. About 65 percent of the oats produced is fed on farms to dairy cattle, calves and work stock. The remainder is sold to local markets and very little is shipped out of the county.

Wheat is the third crop in acreage and value in the county, by far the larger portion of the wheat grown being winter wheat. Average yields of winter wheat amount to 23 bushels per acre, while spring wheat gives an average yield of 13 bushels. Practically all of the winter wheat grown is of the Turkey variety, while the spring varieties used are Marquis and Early Java. Spring wheat has not been very largely grown in the county until recent years, but its acreage has increased considerably recently. Practically all of the wheat produced is disposed of at local flour mills.

The next crop in acreage and value is hay, most of it tame hay, with an average yield of 1.3 tons per acre. Wild hay is produced mainly on the low-lying, poorly drained soils of the Wabash and Bremer series and consists largely of slough grass. There are some areas of prairie grass and some bluegrass. The average yield of wild hay is 1.2 tons per acre. A large portion of the wild hay is sold for packing purposes. The finer varieties, the prairie grass and bluegrass hay, are utilized for feed. Over half of the tame hay produced consists of a

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mixture of red clover and timothy; each of these crops is also grown alone on rather considerable areas.

Alfalfa is grown on a comparatively small area in the county, but this crop is becoming more popular as its value is being more generally recognized and more is learned regarding the methods of securing good stands. Average yields of 2.3 tons per acre are secured. More knowledge of the value of alfalfa for feeding purposes will certainly lead to a considerable increase in the acreage devoted to it, inasmuch as the crop will do well on most of the soils of the county.

Potatoes are grown rather extensively in the county and average yields of 89 bushels per acre are secured. The most important varieties are the Early Ohio, Irish Cobbler and Rural New Yorker. Some rye is produced, with average yields of 15 bushels per acre. Barley is a minor crop and of comparatively small value in the county. Millet and Sudan grass are grown on small areas and utilized for hay. Some sorghum is grown and utilized for sirup production.

Sweet corn is a rather important crop in the county, the principal varieties being Stowell's Evergreen and Country Gentleman. It is grown particularly in the vicinity of Altoona, Grimes and south of Maxwell (in Story county). It is utilized by the canning factory in Altoona and at Grimes and sold locally in Des Moines markets.

Sweet potatoes are grown on a small acreage on some of the sandy types of soil and other vegetables are produced on these soils in the vicinity of Des Moines. Watermelons and cantaloupes are grown very successfully on some of the upland types and on the sandy terrace soils.

Fruit growing is practiced to some extent in the county and there are numerous small orchards, chiefly apple orchards. At present there are six commercial orchards in the county ranging from 10 to 40 acres in size. The principal varieties are the Jonathan, Grimes and Ben Davis. Other varieties grown to some extent are the Winesap, Ralls, Blacktwig, Wealthy and Duchess. In 1920, according to the State Department of Agriculture, 93,759 bushels of apples were harvested in the county. The orchards which are carefully cared for, pruned and sprayed, as necessary, give very satisfactory yields. Cherries are grown to a considerable extent but there are no commercial cherry orchards. Grapes are produced rather extensively and there are five commercial vineyards ranging from one to seven acres in size. Some strawberries, raspberries and blackberries are grown, but chiefly for home use. Practically all of the fruit produced in the county is sold in the Des Moines markets.

THE LIVESTOCK INDUSTRY

The livestock industries of the county include the raising and feeding of hogs and beef cattle, dairying, the raising of horses, and the raising and feeding of sheep. Poultry production is also an industry of considerable importance.

The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the character and extent of the livestock industry of the county:

Horses, all ages	12,236
Mules, all ages	1,094
Swine (on farms July 1, 1920)	59,539
Swine (on farms Jan. 1, 1921)	48,447
Cattle (cows and heifers kept for milk)	10,585
Cattle (other cattle not kept for milk)	17,547

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Cattle (all ages)	28,132
Sheep (all ages on farms January 1, 1921)	5,756
Sheep (shipped in for feeding, 1920)	2,009
Sheep (total pounds of wool clipped)	21,982
Poultry (total number on farms January 1, 1921)	275,650
Poultry (number of dozen eggs received 1920)	1,027,949

The raising of purebred hogs is an important industry in the county, the most popular breeds being Poland China, Duroc Jersey and Chester White. Recently there has been some breeding of Hampshires. Many hogs are fattened, large numbers being shipped in for feeding, particularly on farms where cattle are fed. Practically all of the hogs sold go to the Des Moines markets.

Beef cattle are raised to some extent in the county, only a few of them, however, being purebred. There are some purebred Shorthorn and Aberdeen Angus herds, but most of the beef cattle are grade Shorthorns. Most of the beef cattle are raised locally, but some are shipped in for fattening, particularly in the northeast corner of the county and near Grimes. Practically all of the beef cattle sold in the county are disposed of at the packing houses in Des Moines.

Dairying is becoming important in the county. There are many dairy farms and in many cases dairying is combined with general farming. The largest dairy farms have purebred stock, and in all there are about 100 purebred herds in the county. The most popular breeds are the Holstein and Shorthorn, altho there are a number of Jersey and Guernsey herds. The county has a large number of silos and ensilage is an important feed. Most of the milk produced is sold to the distributing companies in Des Moines.

Sheep raising is practiced to some extent and the fattening of sheep is becoming an important practice, particularly near Grimes, where several carloads of western sheep are shipped in each year. Nearly every farmer raises one or more colts and the important breeds are the Percheron and Belgian. Very few draft horses are produced in excess of the home demand, however, and this industry has not been developed to any considerable extent.

GENERAL SOIL CONDITIONS

Crop yields in Polk county are in general very satisfactory, but there are many instances where larger crops could be secured and where the fertility of the soil could be better maintained if proper methods of soil treatment were followed.

In some instances drainage conditions are not entirely satisfactory and the installation of tile would increase crop yields. The drainage system of the county in general is quite adequate and hence it is usually a question of laying a small amount of tile to bring about an entirely satisfactory drainage condition.

Many of the soils of the county are acid and should have applications of lime for the best growth of crops, particularly of legumes. There are many cases where lime is not needed, but it is usually impossible to determine this fact without making special tests. It is very desirable, therefore, that the soils of the county be tested for acidity, particularly the upland types.

The organic matter contained in many of the soils is not sufficient to insure the best crop production and applications of farm manure or the use of green manure crops are needed. Even on the types which are apparently better supplied with organic matter, applications of farm manure have been found to be of value and should be used liberally. This is particularly true on the sandy

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upland and terrace soils which are utilized for trucking purposes. In fact, where truck crops are to be grown, especially liberal applications of farm manure are very desirable. In all cases where the production of farm manure is inadequate to supply the soils, leguminous green manure crops may be used to advantage. Crop residues should always be returned to the soil in order to aid in keeping up the organic matter supply.

The amount of phosphorus in the soils of the county is somewhat variable but in most instances it is rather low and on some of the types, therefore, there is no question but that phosphorus fertilizers will be needed in the very near future, even if they do not prove of value now. On some of the types the supply is much larger and probably these soils will not respond to phosphorus at the present time. There is no method by which the need of phosphorus can be determined except by applying it to small areas and determining the effect on crop yields. Field tests are now under way in the county to determine the need of phosphorus on the more important soil types, but results from these tests are not yet available. For the present, therefore, it can merely be suggested that farmers make tests of phosphorus on their own soils to determine whether these fertilizing materials can be used with profit. They may use both acid phosphate and rock phosphate in such tests and thus determine not only the need of phosphorus, but also which material should be used.

Complete commercial fertilizers may also be tested along with the phosphorus carriers, but their use is not recommended for general farm crops at the present time. If they prove of value on small areas, then they may be applied to large areas with the assurance of profit. There is no objection to the use of complete commercial fertilizers if they prove profitable. These materials frequently do show a profit in truck farming and their use under truck farming conditions may be very desirable.

In some cases erosion is active in the county and demands some method of control. From the methods suggested in a later section of this report one may be chosen which will serve under almost any soil conditions.

THE GEOLOGY OF POLK COUNTY

The geological history of Polk county prior to the invasion of the county by the glaciers is of practically no significance in a consideration of its soils. The original bedrock material has been covered by various glacial deposits to such great depths that the soils of the county are not influenced by the character of the underlying rock material.

Two great glaciers invaded Polk county. Each left behind vast deposits of glacial drift or till. The first of these, known as the Kansan, covered the entire surface of the county and buried the native rock material under a deep deposit. The Kansan drift consists largely of a stiff blue clay containing numerous pebbles and small boulders. Pockets of sand and gravel occur in or above this layer of clay and where the drift has been exposed to weathering, it has changed to a brown or red color thru oxidation. This drift material is exposed at the surface in a few cases in the southern part of the county, where the subsequent drift deposit and the loess covering have been removed. The soils known as the

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Shelby loam and the Lindley fine sandy loam are derived in whole or in part from this Kansan till. These types are both of minor importance in the county and occur under rather rough topographic conditions.

Following the Kansan glaciation, a second great glacier, known as the Wisconsin, covered the northern four-fifths of the county. The drift layer left by this glacier is quite variable in thickness, ranging from 75 feet in the northern part of the area to a few feet at its southern boundary. This drift material is made up of a mixture of clay, silt and sand, with occasional beds of gravel. Two thick beds of gravel are found, one west of Crocker and the other east of Kelsey. Boulders and pebbles occur scattered thruout the drift material and many of the boulders are rather large. In its natural state the drift is bluish-gray to pale yellow in color and it originally contained considerable calcareous material. Thru the process of weathering, however, the carbonates have been very largely washed out in the drainage water except where the soils have been developed under a level topographic condition. The soils derived from this Wisconsin drift material are classified in the Carrington and Webster series, the latter occurring in the more level areas and characterized by a much higher content of organic matter, a blacker color and considerable amounts of carbonates. The Carrington soils are lighter in color and have lost the greater portion or all of their carbonate content.

Above the drift in the southern part of the county there has been deposited a thin covering of a silty material known as loess. This is supposed to have been deposited by the wind at some previous geological time when climatic conditions were very different than at present. About one-fifth of the county is covered by the loess, extending from the western boundary, where it is three and one-half miles in width, over a gradually widening area to the eastern boundary, where it is about nine miles wide. It varies considerably in depth, averaging from 10 to 20 feet. It is characterized by a buff color and the absence of pebbles and boulders. A few small pockets of sand are occasionally found, but these are of very minor occurrence. Originally this loessial material was probably well supplied with lime nodules but at the present time these have all been removed by leaching and the soils are acid. The soils derived from this loessial material are classed in the Tama and Clinton series. The Tama silt loam is the most important loess type and occupies a rather extensive acreage. The Clinton silt loam is of minor occurrence. The former type is characterized by an undulating to gently rolling topography, while in the case of the Clinton soils the topography is rolling to rough. The Tama silt loam has been produced from the weathering and accumulation of organic matter in this loess covering under prairie conditions. Hence it is rather dark in color. The Clinton silt loam, on the other hand, has been produced under forested conditions and the color is much lighter.

The terrace and bottomland soils of the county are derived from the reworked glacial and loessial material of the upland. The older and higher terraces are found in the Wisconsin drift region and they lie 15 to 40 feet above the present flood plain of the larger streams. These soils are extremely variable in texture and in some instances are characterized by layers of sand and gravel, while in other cases the lower layers are heavy and made up mainly of clay. These older terraces are grouped in the O'Neill, Waukesha, Buckner and Chariton series.

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drainage is poorly developed and there are many farms that are still in need of tiling. Much of these areas just mentioned was originally in a marshy condition and there are many meandering sloughs which eventually empty into the larger streams. The fall, however, is slight and in most instances the natural drainage in these areas is very poor. Along the steeper slopes of the Des Moines river drainage is often excessive. There is very little of the county, however, in which this is true.

The natural drainage system of the county is shown in the accompanying drainage map, and the areas of poor drainage are very largely indicated, altho it would seem from the map that drainage should be more satisfactory in some areas than is actually the case. This is due to the fact that there is so little fall in many of the intermittent drainage channels that the water moves down them at a very slow rate and consequently the land retains considerable amounts of moisture over long periods of time.

THE SOILS OF POLK COUNTY

The soils of Polk county are grouped into four classes according to their origin and location. These are loess soils, drift soils, terrace soils and swamp and bottomland soils. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were different that at present. Drift soils are deposits left by glaciers upon their retreat and they are made up of material from various sources and contain sand, gravel and boulders. The terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the stream which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas or along streams and they are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Polk county are shown in table II.

Over one-half of the total area of the county, 60.1 percent, is covered by drift soils. The loess soils are second in area, covering 14.5 percent of the county. Terrace soils are minor in extent, covering 11.4 percent of the county, while the swamp and bottomland soils are rather extensive, covering 14.0 percent of the total area of the county.

There are 31 individual soil types in the county, and these with the shallow phase of the Carrington loam and the shallow phase of the Tama silt loam and the areas of riverwash and muck and peat, make a total of 35 separate soil areas.

There are six drift soils in the county, and a small area of the shallow phase of the Carrington loam, making a total of seven drift soils. There are three loess types and an area of the shallow phase of the Tama, making four loess soils. There are eleven terrace types and eleven swamp and bottomland types which, together with the areas of riverwash

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN POLK COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	223,232	60.1
Loess soils	54,528	14.5
Terrace soils	42,368	11.4
Swamp and bottom land soils	52,352	14.0
Total	372,480	....

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and muck and peat, make thirteen bottomland soils. These various soils are distinguished on the basis of certain characteristics which are described in the appendix to this report and the names denote certain group characteristics.

The areas of the various soil types of the county are shown in table III. The Carrington loam is by far the largest individual soil type as well as the largest drift soil. The Webster clay loam is the second largest drift type and it is the second type in area in the county, covering 17.0 percent of the total area. The Tama silt loam is the largest loess type and the third largest type in the county. The terrace types are all minor in area, the largest being the Waukesha loam, which covers 3.7 percent of the county.

The swamp and bottomland soils in the county are likewise all small in area, the most extensive being the Wabash clay, which covers 4.1 percent of the county.

The uplands of the county are covered by the drift and loess soils and in the case of the former types the topography is almost level to gently undulating. Where the loess soils occur, however, in the southern part of the county, the

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN POLK COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	118,656	32.9
142	Carrington loam (shallow phase)	3,584	
56	Webster clay loam	63,168	17.0
107	Webster silty clay loam	16,256	4.4
4	Carrington fine sandy loam	9,280	2.5
136	Lindley fine sandy loam	6,976	1.9
79	Shelby loam	5,312	1.4
	LOESS SOILS		
120	Tama silt loam	37,056	11.1
143	Tama silt loam (shallow phase)	4,608	
80	Clinton silt loam	12,352	3.3
145	Tama loamy fine sand	512	0.1
	TERRACE SOILS		
60	Waukesha loam	13,696	3.7
43	Bremer silty clay loam	6,656	1.8
110	O'Neill fine sandy loam	4,928	1.3
88	Bremer silt loam	4,480	1.2
12	Bremer loam	3,328	0.9
45	Buckner fine sandy loam	2,752	0.7
75	Waukesha silt loam	2,560	0.7
108	O'Neill loam	2,048	0.6
44	Bremer clay	1,088	0.3
146	O'Neill fine sand	512	0.1
105	Chariton silt loam	320	0.1
	SWAMP AND BOTTOMLAND SOILS		
72	Wabash clay	15,168	4.1
49	Wabash loam	8,512	2.3
91	Sarpy loam	6,464	1.7
111	Lamoure silty clay loam	5,184	1.4
144	Sarpy silty clay loam	4,800	1.3
28	Sarpy very fine sandy loam	3,328	0.9
48	Wabash silty clay loam	2,816	0.8
26	Wabash silt loam	1,920	0.5
89	Sarpy silt loam	1,280	0.3
53	Riverwash	896	0.2
21	Muck and peat	832	0.2
62	Wabash fine sandy loam	640	0.2
102	Sarpy fine sandy loam	512	0.1

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topography is more rolling. Hence the Tama silt loam has a characteristic rolling topography and the Clinton silt loam is strongly rolling to rough. The drift types of the Webster and Carrington series on the other hand vary from level to gently rolling.

Along the streams of the county the topography is quite different than on the uplands which separate the streams. Frequently the rivers flow thru deep valleys with sharply rising bluffs leading to the uplands. In some areas erosion has been very active and the loess covering and the more recent drift layer have been washed away, exposing the earlier drift formation. Here the soils of the Shelby and Lindley series are found and these are characterized by a strongly rolling to steep or rough topography.

The terraces and bottomlands are usually rather level, altho in some cases the terraces have been eroded to some extent and do not appear as level as would be expected. The bottomlands are very largely subject to overflow and in some instances are poorly drained.

The need of drainage is apparently very closely related to the topographic conditions of the soils in the county. The more level drift soils and the bottomland soils are poorly drained in many instances, while the rolling drift types and the loess soils are quite adequately drained.

THE FERTILITY IN POLK COUNTY SOILS

Samples were taken for analyses from each of the soil types in the county, except the shallow phase of the Carrington loam. The areas of muck and peat and riverwash were not sampled, because the analyses of these materials would be of very little significance. The more extensive types were sampled in triplicate, while one sample only was taken in the case of the minor types.

All samplings were made with the greatest care that the soils should be representative and that variations due to local conditions and special treatments should be eliminated. Samplings were made at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches and 20 to 40 inches, representing the surface soil, the subsurface soil and the subsoil, respectively. The samples were analyzed for total phosphorus, nitrogen, organic carbon, inorganic carbon and limestone requirement. The official methods were employed for the phosphorus, nitrogen and carbon determination and the Veitch method was employed in determining the limestone requirement. The figures given in the tables are the averages from the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soil are given in table IV. They are calculated in pounds per acre on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the soils of the county is quite variable, ranging from 1,043 pounds in the Tama loamy fine sand up to 3,360 in the Bremer clay. The latter amount, however, is considerably higher than that found in most of the types in the county. There seems to be practically no relation between the phosphorus supply and the soil group, altho the bottomland types on the average

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TABLE IV. PLANT FOOD IN POLK COUNTY SOILS

Pounds per acre of Two Million Pounds of Surface Soil (0"—6 2/3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	1,436	3,941	45,306	0	4,204
56	Webster clay loam	1,723	5,636	68,086	1,360	Basic
107	Webster silty clay loam	2,101	9,836	114,816	22,104	Basic
4	Carrington fine sandy loam	1,252	1,710	19,960	0	5,005
136	Lindley fine sandy loam	1,205	2,074	36,266	Trace	Basic
79	Shelby loam	2,175	2,858	33,840	0	2,145
	LOESS SOILS					
120	Tama silt loam	2,040	4,176	48,260	0	4,290
143	Tama silt loam (shallow phase)	1,151	2,396	25,000	0	2,502
80	Clinton silt loam	1,764	3,278	35,460	0	1,430
145	Tama loamy fine sand	1,043	2,088	33,420	0	2,145
	TERRACE SOILS					
60	Waukesha loam	3,024	2,886	34,140	0	4,290
43	Bremer silty clay loam	2,889	4,624	61,220	0	3,932
110	O'Neill fine sandy loam	1,508	2,326	28,880	0	3,932
88	Bremer silt loam	2,161	4,554	65,420	0	3,932
12	Bremer loam	1,737	2,564	32,940	0	715
45	Buckner fine sandy loam	1,616	2,283	21,620	0	4,747
75	Waukesha silt loam	1,953	3,978	47,640	0	3,575
108	O'Neill loam	1,899	3,516	36,280	0	5,005
44	Bremer clay	3,360	6,094	81,390	1,070	Basic
146	O'Neill fine sand	1,245	1,050	6,360	0	2,502
105	Chariton silt loam	1,656	3,810	45,540	0	5,005
	SWAMP AND BOTTOMLAND SOILS					
72	Wabash clay	2,343	4,442	60,308	532	Basic
49	Wabash loam	2,289	2,984	32,846	3,094	Basic
91	Sarpy loam	1,865	2,732	30,121	9,039	Basic
111	Lamoure silty clay loam	2,330	7,888	89,044	11,696	Basic
144	Sarpy silty clay loam	1,501	2,900	33,494	11,646	Basic
28	Sarpy very fine sandy loam	2,155	1,556	15,544	18,596	Basic
48	Wabash silty clay loam	2,916	3,236	38,936	644	Basic
26	Wabash silt loam	2,276	3,670	42,920	0	4,747
89	Sarpy silt loam	1,865	2,844	28,500	440	Basic
62	Wabash fine sandy loam	1,993	1,836	31,600	4,540	Basic
102	Sarpy fine sandy loam	1,495	1,304	14,944	Trace	Basic

are somewhat better supplied with this constituent than the terrace and upland soils. This condition would be expected, inasmuch as many of the bottomland soils have been uncultivated and uncropped and hence there has been very little removal of phosphorus. The drift soils on the average seem to be somewhat better supplied with phosphorus than the loess soils, while the terrace types are extremely variable. There seems to be more of a relation between the soil texture and the phosphorus supply than is true in the case of the soil groups. In a general way the sandier types are lower in phosphorus, while the clay soils are much better supplied. The Carrington fine sandy loam is lower in phosphorus than the Carrington loam. The Tama loamy fine sand is very much lower than the Tama silt loam, containing the least amount of phosphorus of any type in the county. The O'Neill fine sand is lower in phosphorus than the fine sandy loam of the same series and this in turn is lower than the O'Neill loam. There is only one exception to this general rule and that is in the case of the Sarpy very fine sandy loam, which is particularly high in phosphorus, higher even than

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the loam and silt loam. This, however, is an abnormal condition and other factors than the soil texture are involved in the composition of this soil, which is a minor bottomland type. In the case of the other types in this series there seems to be some relation to the soil texture. Thus the Sarpy fine sandy loam contains less phosphorus than the Sarpy loam and also a smaller amount than the silt loam.

There seems to be some relation, too, between the phosphorus supply and the soil series. The Webster soils of the upland are higher than the Carrington soils and the Lindley series is particularly low. The Tama soils of the loessial upland are better supplied than the Clinton areas. The Bremer and Waukesha soils of the terraces are very much higher in phosphorus than the O'Neill and Buckner types and among the bottom types the Wabash soils and the Lamoure soils are in general higher in phosphorus than the Sarpy series. There is undoubtedly some relation here between the particular characteristics of the soils which determine the series in which they are placed and the phosphorus supply.

It is quite evident that there is no large supply of phosphorus in any of the soils of the county, and phosphorus fertilizers will undoubtedly be needed in the near future if the soils are to be kept satisfactorily productive. It may be that applications of phosphorus fertilizers would prove of considerable value at the present time in some instances. Even altho there is an abundance of phosphorus present in a soil, there may be a lack of the element in an available form and where this is true the application of a soluble fertilizer would prove of considerable economic value. There is no way to determine accurately the amount of available phosphorus in the soil except to apply a soluble phosphorus fertilizer and determine its effect on crop yields. If it brings about an increase then the conclusion may be drawn that available phosphorus is lacking in the soil. Such tests are strongly urged. On the individual farm they are of particular value in showing the needs of individual soils and they also permit of conclusions regarding the relative value of the various phosphorus carriers, and particularly, rock phosphate and acid phosphate.

The total nitrogen content of the soils of the county is quite variable, ranging from 1,050 pounds per acre in the O'Neill fine sand up to 9,836 pounds in the Webster silty clay loam. In some instances there seems to be an abundance of nitrogen, but in most of the types the amount present is sufficient to keep crops supplied for only a short time.

There is no apparent relation between the nitrogen content and the soil group. The bottomland soils, which are ordinarily better supplied with nitrogen than the other groups, show about the same average amount as the uplands. The same is true of the terrace types. There is some relation, however, between the soil texture and the soil series and the nitrogen content. The Webster soils are higher in nitrogen than the Carrington soils. The Tama soils are higher than the Clinton types; the Bremer and the Waukesha soils on the terraces are generally higher than the O'Neill series. The Wabash and Lamoure soils of the bottomlands contain more nitrogen than the Sarpy soils. There are some exceptions to these comparisons, however. For example, the O'Neill loam on the terrace is higher than the Waukesha loam and it is also higher than the Bremer loam, but in general the soils of this series are lower than the others.

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As to soil texture and nitrogen content, the heavier textured soils contain more nitrogen in most cases than the lighter textured types. Thus, the Carrington fine sandy loam is lower than the Carrington loam. The Tama loamy fine sand is lower than the silt loam. The Bremer loam is lower than the silty clay loam and the clay. The Waukesha loam is lower than the silt loam. The O'Neill fine sand is lower than the O'Neill loam and among the bottom types the Wabash loam is lower than the silt loam, silty clay loam and clay, while the Wabash fine sandy loam contains less nitrogen than the loam.

The analyses of these soils as a whole show that nitrogen must not be disregarded in systems of permanent soil fertility in this county. With the exception of a very few of the types, precautions should be taken at once to see that the nitrogen supply is built up. Where the nitrogen supply is inadequate, crops may be unsatisfactory for this reason. Farm manures and crop residues return to the soil some nitrogen and aid materially in keeping up the content of this element. They do not return all of the nitrogen removed by crops, however, and even when they are employed, the nitrogen supply in the soils gradually decreases. Leguminous crops turned under as green manures are often necessary in addition to farm manures and crop residues to build up and maintain the nitrogen content of the soil. When these crops are well inoculated they take from the atmosphere a large part of the nitrogen which they contain. When they are turned under, this nitrogen becomes available for the use of subsequent crops, providing a cheap and very desirable method of adding nitrogen to the soil. This method should undoubtedly be followed to some extent in keeping up the nitrogen in Polk county soils.

The organic carbon content of the soils is always very closely related to the nitrogen content and the supply of both bears a definite relation to the color of the soil. If the soil is dark in color it is well supplied with organic matter and usually also with nitrogen. On the other hand, if it is light in color the organic matter content is low and nitrogen is probably deficient. The ratio of nitrogen to organic carbon in soils gives some indication of the extent or rapidity of the decomposition processes and hence of the rate of production of available plant food. If the decomposition of the organic matter in soils is too slow plants may suffer from a lack of available plant food. If the amount of carbon in relation to nitrogen falls below a certain ratio, it may be rather definitely concluded that the production of available plant food is not proceeding satisfactorily.

On most of the soil types in Polk county the relation between the nitrogen and organic carbon is such that it is quite certain that the decomposition of the organic matter is going on quite satisfactorily. There are a few exceptions to this, particularly in the case of some of the lighter textured types where the total supply of organic matter is too low. In all these cases it is especially necessary that farm manure be used. This material stimulates the production of available plant food besides adding organic matter. Where farm manure is not available in sufficient amounts, leguminous green manures should be used as supplements. Crop residues should be utilized in all cases. Even on some of the types apparently better supplied with organic matter, the application of farm manure has been found to be of value, probably due to the fact that it stimulates the production of available plant food. But whatever the reason for its beneficial effect,

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Fig. 2. Level Webster clay loam topography.

it is certain that the use of this fertilizing material on most of the soils of the county pays.

In handling practically all of the soils of Polk county, care needs to be taken to keep up the supply of organic matter. Too much emphasis cannot be placed upon the proper use of crop residues and the proper preservation and application of all the manure produced on the farm, and if these materials are inadequate, the use of leguminous crops as green manures.

The upland soils of the county, with the exception of those in the Webster series, are generally acid and contain no inorganic carbon. The Lindley fine sandy loam does not appear to be acid in this particular test, but this is not generally true for this soil type. The Webster soils are usually not acid and contain at least small amounts of lime. They may need a small application of lime when the surface soil is acid and this sometimes occurs. The subsoils of the types of this series are never acid, but if the surface soil is acid, lime should be applied. The loess types are all acid and all but one of the terrace types are acid and in need of lime. Of the bottomland soils of the county only one type shows acidity according to the tests. Some others of the soils tested here do, however, show an acid reaction in other samples, especially the Wabash soils. It is apparent from the results that all of the upland types except those of the Webster series and all of the terrace types should be tested for acidity and the lime shown to be necessary by the tests should be applied if the crops grown are to be satisfactory. This is particularly true in the case of legumes. The bottomland types of the county apparently are not in need of lime at present except in a few instances.

The figures given in the table showing the lime requirements of the soils are merely indicative of the needs of the various types and should not be taken to show definitely how much lime these soils will need. The lime requirement of soils is extremely variable, even under apparently identical conditions. Hence the soil from every field should be tested for lime requirement before any appli-

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cation is made. There is no question but that the best crop growth, especially of legumes, cannot be secured on many of the soils in Polk county unless they are tested and lime is applied. In fact, with only one exception, there is not sufficient lime content in the upland soils or terrace types to keep this material from becoming deficient in the near future and in four of the bottomland types the lime supply is low and will soon be lacking.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the surface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil. In general, the plant food content of the lower layers of soil has very little influence on the fertility of the soil and on the treatments needed unless there are some large amounts of plant food constituents present. In the soils of Polk county the subsurface soils and subsoils are not any higher in any constituent than the surface soils and in most cases the content of plant food constituents is less. Hence it is unnecessary to consider these analyses in detail.

TABLE V. PLANT FOOD IN POLK COUNTY, IOWA, SOILS

Pounds per acre of Four Million Pounds of Subsurface Soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	2,541	4,950	50,507	0	4,528
56	Webster clay loam	2,828	4,997	61,844	1,656	Basic
107	Webster silty clay loam	3,367	12,748	138,344	38,176	Basic
4	Carrington fine sandy loam	2,397	3,084	37,560	0	9,495
136	Lindley fine sandy loam	2,007	2,408	25,400	0	1,430
79	Shelby loam	3,987	3,728	41,920	680	Basic
	LOESS SOILS					
120	Tama silt loam	3,596	7,284	79,320	0	6,434
143	Tama silt loam (shallow phase)	2,087	3,392	29,600	0	5,004
80	Clinton silt loam	2,411	3,140	27,240	0	5,720
145	Tama loamy fine sand	2,505	3,840	33,400	0	3,574
	TERRACE SOILS					
60	Waukesha loam	3,825	5,520	62,360	0	8,580
43	Bremer silty clay loam	4,337	6,472	61,220	0	6,434
110	O'Neill fine sandy loam	2,465	4,652	50,080	0	5,720
88	Bremer silt loam	3,987	7,844	100,840	0	7,864
12	Bremer loam	2,491	9,136	141,756	724	Basic
45	Buckner fine sandy loam	2,357	4,567	50,320	0	5,720
75	Waukesha silt loam	4,121	5,548	61,640	0	5,004
108	O'Neill loam	2,667	5,044	56,560	0	7,150
44	Bremer clay	4,472	5,716	91,264	1,256	Basic
146	O'Neill fine sand	3,057	2,156	10,688	472	Basic
105	Chariton silt loam	2,411	3,868	43,680	0	7,864
	SWAMP AND BOTTOMLAND SOILS					
72	Wabash clay	3,381	5,828	71,520	960	Basic
49	Wabash loam	4,499	5,912	69,984	4,216	Basic
91	Sarpy loam	3,569	6,080	56,516	14,844	Basic
111	Lamoure silty clay loam	2,694	9,416	92,572	6,188	Basic
144	Sarpy silty clay loam	3,461	6,416	72,984	17,736	Basic
28	Sarpy very fine sandy loam	4,256	2,044	16,120	39,640	Basic
48	Wabash silty clay loam	4,512	5,464	65,360	0	3,574
26	Wabash silt loam	4,984	7,928	49,460	0	6,434
89	Sarpy silt loam	2,882	4,008	38,292	548	Basic
62	Wabash fine sandy loam	4,916	5,352	57,068	5,292	Basic
102	Sarpy fine sandy loam	2,249	2,380	27,348	452	Basic

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TABLE VI. PLANT FOOD IN POLK COUNTY, IOWA, SOILS

Pounds per acre of Six Million Pounds of Subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
1	Carrington loam	3,522	4,190	35,520	0	4,747
56	Webster clay loam	3,044	2,772	49,267	10,620	Basic
107	Webster silty clay loam	2,748	3,738	54,498	12,282	Basic
4	Carrington fine sandy loam	2,990	2,436	98,760	0	9,652
136	Lindley fine sandy loam	3,980	2,940	27,924	18,036	Basic
79	Shelby loam	5,192	2,310	19,920	37,080	Basic
	LOESS SOILS					
120	Tama silt loam	4,647	5,214	46,500	0	4,290
143	Tama silt loam (shallow phase)	4,626	3,276	23,280	0	14,242
80	Clinton silt loam	5,233	3,612	30,600	0	4,290
145	Tama loamy fine sand	2,444	1,932	16,572	828	Basic
	TERRACE SOILS					
60	Waukesha loam	4,647	3,570	43,980	0	8,580
43	Bremer silty clay loam	5,212	5,298	66,300	0	9,653
110	O'Neill fine sandy loam	3,354	4,416	50,940	0	4,290
88	Bremer silt loam	5,475	6,348	91,380	0	11,796
12	Bremer loam	3,677	3,570	70,020	1,080	Basic
45	Buckner fine sandy loam	2,889	2,772	25,740	0	3,517
75	Waukesha silt loam	6,344	3,996	45,120	0	6,435
108	*O'Neill loam					
44	Bremer clay	5,475	4,500	75,843	1,677	Basic
146	O'Neill fine sand	5,354	1,890	8,172	768	Basic
105	Chariton silt loam	3,596	5,004	25,400	0	9,652
	SWAMP AND BOTTOMLAND SOILS					
72	Wabash clay	5,778	5,088	74,904	1,356	Basic
49	Wabash loam	6,445	5,046	53,796	1,944	Basic
91	Sarpy loam	4,203	6,684	70,002	26,718	Basic
111	Lamoure silty clay loam	4,162	4,542	64,554	2,946	Basic
144	Sarpy silty clay loam	5,233	9,540	104,142	25,218	Basic
28	Sarpy very fine sandy loam	6,283	2,646	19,092	62,388	Basic
48	Wabash silty clay loam	5,879	4,962	66,960	0	4,290
26	Wabash silt loam	8,546	6,600	96,960	0	5,362
89	Sarpy silt loam	4,465	3,696	31,868	8,412	Basic
62	Wabash fine sandy loam	8,728	7,692	81,324	7,956	Basic
102	Sarpy fine sandy loam	3,435	2,142	20,490	7,470	Basic

*Not analyzed.

The needs of the soils of the county which have been evidenced from the analyses of the surface soils are apparently borne out by the analyses of the lower soil layers. In several cases the lower soil layers are not acid where the surface soil is acid, but in only one of these cases, however, is the actual amount of lime present sufficient to influence to any extent the lime content of the surface soil. Lime rarely moves upward in the soil in any case and hence it may be concluded that the test of the surface soils shows definitely the needs of the soils of this county.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Polk county to learn something of their fertilizer needs and of the value of applications of certain fertilizing materials. These experiments were carried out on the Carrington loam and the Webster clay loam, the two major soil types in the county. In addition, the results of an experiment on the Tama silt loam from Marshall

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TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, POLK COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	5.50	27.21
2	Manure	11.50	40.82
3	Manure+lime	11.50	48.89
4	Manure+lime+rock phosphate	13.00	52.16
5	Manure+lime+acid phosphate	13.50	56.69
6	Manure+lime+complete commercial fertilizer	15.50	56.69

county are included in this report, inasmuch as this is a rather important type in the southern part of Polk county and the results should be applicable to Polk county conditions.

The arrangement of all the experiments was the same and consisted in the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts of these various materials applied were the same as are used in the field experiments, and hence the results of these greenhouse tests may be considered to indicate quite definitely what would be expected in the field. Manure was applied at the rate of eight tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil as indicated by the Veitch test and to supply two tons additional. Rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments, the clover being seeded about one month after the wheat was up. The results of the experiment on the Carrington loam from Polk county are given in table VII, the figures being the averages of the yields on the duplicate pots.

The effect of the manure showed up very definitely on both the wheat and clover crops, as it has many times in farm experience and there is no question

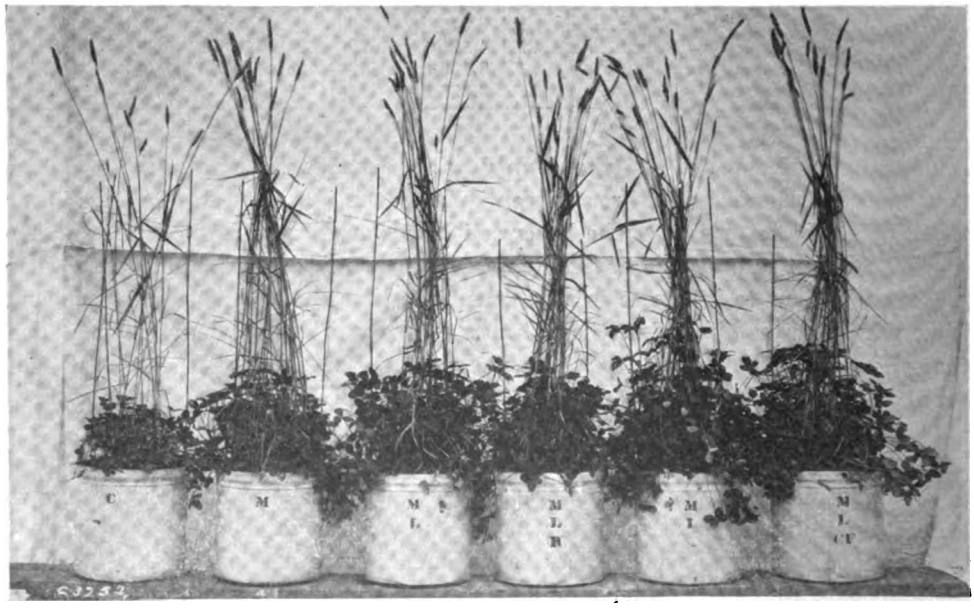

Fig. 3 Greenhouse experiment, wheat and clover on Carrington loam, Polk County.

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Fig. 4 Clover on Carrington loam, Polk county.

but that this material is of large value on the Carrington loam in Polk county. The application of lime along with manure had no effect on the wheat crop, but it did bring about a distinct increase in the clover. It is not ordinarily expected that lime will have any large influence on the growth of small grains, but its use is well warranted by its influence on the legume in the rotation. The application of rock phosphate along with manure and lime increased the growth of both the wheat and the clover, the effect being particularly noticeable in the case of the latter crop. Acid phosphate gave an increase very similar to the rock phosphate in the case of the wheat but brought about a larger effect on the clover. The complete commercial fertilizer, on the other hand, showed a larger effect on the wheat but the same influence on the clover as did the acid phosphate.

It is apparent from these results that manure is a particularly valuable fertilizer for the Carrington loam in this county; they confirm the results obtained on the same soil type in many other counties. As noted above, the results are also borne out by considerable field experience.

The use of lime in addition to manure is necessary on the Carrington loam if the best growth of legumes is to be secured, and it should be noted that there is a secondary effect of the lime on the grain crops in the rotation, a beneficial influence which results from a greater clover or other legume growth. The need of testing this soil for acidity is evidenced and the importance of applying the amount of lime shown to be necessary is emphasized. There is rather definite evidence of the value of phosphorus fertilizers on this soil, both for wheat and for clover. It is not possible to determine the relative value of rock phosphate and acid phosphate, however, from these results, altho it might perhaps seem that acid phosphate has somewhat more effect on the clover. The differences are too small for definite conclusions. The complete commercial fertilizer seems to be somewhat preferable for wheat but has no advantage on clover. Again, however, the results are not definite enough to warrant recommendations.

The second greenhouse experiment was on the Webster clay loam from Polk county. The results of the experiment are given in table VIII.

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TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER CLAY LOAM, POLK COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	14.25	68.04
2	Manure	20.25	81.64
3	Manure+lime	20.50	86.18
4	Manure+lime+rock phosphate	21.00	90.72
5	Manure+lime+acid phosphate	23.00	90.72
6	Manure+lime+complete commercial fertilizer	20.50	90.72

Manure apparently exerts a beneficial effect on the growth of wheat and clover on the Webster clay loam, considerable increases in crop yields being obtained with both these crops. This effect of manure is rather surprising on this soil type, as it is apparently well supplied with organic matter and it would not be expected that large effects would be evidenced by the use of manure. It may be that in this case the manure stimulates the production of available plant food to such a large extent that crops are benefited. The use of lime in addition to manure had no effect on the wheat and a slight effect on the clover. This particular soil type is usually not acid in the surface soil and not in need of lime. The sample used in this experiment was slightly acid and the addition of lime proved of value on the clover crop. The application of the phosphorus fertilizers gave slight increases in the wheat and also in the clover. The acid phosphate seemed to be somewhat more beneficial in the case of the wheat but all the materials used showed similar results in the case of the clover. Complete commercial fertilizer showed less effect than the phosphorus carriers in the case of the

Fig. 5 Wheat and clover on Webster clay loam, Polk county greenhouse experiment.

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TABLE IX. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY.

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+lime	23.50	49.89
4	Manure+lime+rock phosphate	24.00	54.43
5	Manure+lime+acid phosphate	27.50	72.63
6	Manure+lime+complete commercial fertilizer	24.00	63.50

wheat and gave the same results on the clover. These results indicate that manure is a valuable material for use on this soil and moderate applications should be made in order to stimulate plant food production and thus increase crop growth. Lime should be applied to the soil wherever it shows an acid reaction. There is evidence of value from the use of phosphorus fertilizers and tests should be carried out to determine the relative value of acid phosphate and rock phosphate on the individual farm. The complete commercial fertilizer showed less effect than the phosphorus carriers and it would seem that the latter would probably prove of more value on this soil type than any complete brands.

The results from the greenhouse experiment on the Tama silt loam in Marshall county are given in table IX.

The application of manure to this soil proved distinctly beneficial to the wheat crop but had apparently no effect on the clover. The use of lime in addition to manure gave no influence on the wheat but brought about a distinct gain in the growth of clover. The addition of phosphate fertilizers proved beneficial on both crops, the acid phosphate showing up very much better than the rock in both cases. The clover crop was increased to a very large extent by the use of this material. The complete commercial fertilizer had no advantage over rock phosphate in the case of the wheat but showed up somewhat better on the clover. It had less effect, however, on the clover than did the acid phosphate. It seems apparent from these results that manure is a valuable fertilizing material for use on this soil type and this material should be used wherever available for building up the fertility of the soil. Lime should be applied to the soil in proper amounts, which may be determined by tests, if the best growth of legumes is to be secured. Applications of phosphorus fertilizers are apparently of value and there is evidence of a larger effect from the use of acid phosphate than from the use of rock. These results should not be considered conclusive, however, and field tests must be carried out to determine definitely the relative merits of these two materials. Complete commercial fertilizers do not have any particular advantage over phosphorus carriers on this soil and indeed actually give smaller effects. Hence they cannot be recommended for use on this soil at the present time.

FIELD EXPERIMENTS

The field experiments which are under way in Polk county have not yet been carried on long enough to permit of conclusions from the results secured. However, some experiments have been under way for several years on the Agronomy

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Farm at Ames in Story county on the Carrington loam, which is the most extensive soil type in Polk county. The results of these experiments are not entirely conclusive as yet and it is intended that they shall be carried on for a much longer period before definite conclusions are drawn. There are indications from some of the experiments, however, of the value of various fertilizing materials and hence the results of one of these experiments are given in this section of the report.

One of the experiments on the Agronomy Farm at Ames on the Carrington loam is arranged in five series of plots and on these plots there is practiced a five-year rotation consisting of corn, oats, clover, wheat and five years of alfalfa, the four-year rotation of corn, oats, clover, wheat being repeated five times and then the land left in alfalfa for five years on each series of plots. These experiments were started in 1915, but the yields that year and in 1916 are not included in the averages owing to the fact that they were undoubtedly abnormal and the effects of treatment did not show up satisfactorily until the third year of the experiment. The entire series of plots in this five-year rotation experiment includes tests with manure and with crop residues, representing the livestock system of farming and the grain system of farming. Only the manure plots are discussed here, as the crop residue plots have not yet given results of definite value. The treatments on these plots consist of application of manure, lime, rock phosphate and acid phosphate. The application of manure is made at the rate of eight tons per acre once in four years, rock phosphate at the rate of 2,000 pounds per acre once in four years and acid phosphate at the rate of 200 pounds annually. Lime is used in sufficient amounts to neutralize the acidity of the soil and supply two tons additional.

The yields secured of the various crops grown in this five-year rotation during the years 1917, 1918, 1919, 1920 and 1921, are given in table X. During these five years there were grown on the five series of plots, five crops of corn, six of oats, three of wheat, five of alfalfa, three of clover, one of barley and two of soybeans. The soybean crops were used when clover failed and the barley was grown when the wheat crop failed. The results given in the table are the averages of all the crops grown during the five years, the checks being the average of duplicate checks in each series of plots.

Examining the results given in this table, it will be noted that the addition of manure in this five-year rotation increased to a large extent the yields of all the crops grown in the rotation. The effect of the manure was particularly noticeable on the corn and clover of the rotation. Apparently the Carrington loam

TABLE X. FIELD EXPERIMENT, CARRINGTON LOAM, STORY COUNTY, AMES FIELD

Treatment	Corn bu. per acre 5 crops	Oats bu. per acre 6 crops	Wheat bu. per acre 3 crops	Alfalfa tons per acre 5 crops	Clover tons per acre 3 crops	Barley bu. per acre 1 crop	Soybeans tons per acre 2 crops
Check	53.5	49.6	17.9	1.16	1.70	11.0	2.12
Manure	67.8	56.4	24.3	1.26	2.62	12.2	2.56
Manure+lime	67.7	59.8	26.6	1.43	2.81	17.1	2.26
Manure+lime+rock phosphate	72.2	61.6	27.4	1.58	2.95	19.4	2.59
Manure+lime+acid phosphate	70.3	62.7	33.3	1.75	3.40	17.8	2.50

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in this rotation will respond very profitably to applications of farm manure and it is evidently a very important fertilizing material for use on this soil type. Farmers are urged to carefully preserve and apply all the manure produced on their farms and they may thus increase their crop yields and aid in keeping their soils fertile.

The use of lime in addition to manure brought about small increases in the oats and wheat crops but exerted a pronounced effect on the alfalfa and clover. The results obtained with the soybeans were evidently somewhat abnormal, but as the results are the averages of only two crops of soybeans, the decrease noted in the table should not be considered of significance. It would be expected that lime would show the greatest effect on the legumes of the rotation and this expectation is borne out by the results secured. It is interesting to note, however, that the oats, wheat and barley were all increased to a considerable extent by this material.

The application of phosphate fertilizers is apparently of some value on the Carrington loam, both the rock phosphate and the acid phosphate giving increases in yields, many of them being very considerable. There seems to be a considerable difference in the effect of these two materials on the different crops of the rotation. For example, the acid phosphate shows up to very much better advantage on the wheat than does the rock phosphate and similarly in the case of the clover the effect of the acid phosphate is very much more pronounced. With the corn and oats, however, there is very little difference between the two materials. With the alfalfa, acid phosphate seems to have a somewhat greater effect. It seems evident from these results that the application of phosphorus fertilizers may be of considerable value on the Carrington loam in Polk county at the present time. Definite recommendations regarding the use of phosphorus or regarding which phosphate fertilizer should be employed cannot be given from the data at present available. It seems safe to say, however, that phosphorus fertilizers will probably prove of value and farmers are urged to test the use of both rock phosphate and acid phosphate in the effort to determine which will be of the most value under their particular soil conditions.

THE NEEDS OF POLK COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

Field experiments are now under way in Polk county and in the course of the next few years results will be available to indicate the fertilizing materials which may be used with profit in this county. For the present, the suggestions regarding treatments which will be made here are based on the laboratory and greenhouse tests and on the field tests in other counties. They are also based, however, on much field experience, and no recommendations are made which have not been proven to be of value by practical experience. Where definite data on the effects of various materials are not available, as in the case of phosphorus, recommendations are made that tests be carried out on individual farms. When farmers test the use of these materials under their own conditions, they may then secure first hand knowledge of their value and until the field experiments now

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under way are completed, this is the only definite recommendation which can be made regarding the use of phosphorus fertilizers. The suggestions made in the following pages should be understood to be of proven value and any of them may be put into operation under general farm conditions.

MANURING

The soils of Polk county are not strikingly deficient in organic matter content except in a few instances, but neither are they very well supplied and additions of farm manure would be of considerable value on practically all of the types in the county. Only in the case of the Webster silty clay loam is there any extremely large amount of organic matter present, and even in this case the addition of a small amount of manure to stimulate the production of available plant food would be of value in increasing crop yields. The experiments reported in the preceding pages and the experience of many farmers gives very definite support to the statement that manure is a most valuable fertilizer for use on the soils of the county. It always brings large increases in crop yields and in most cases the addition of other fertilizers would not be of value unless manure were also applied. On sandy soils, and especially where truck crops are grown, the addition of manure is particularly valuable and in some instances absolutely necessary for the best growth of crops. In all cases, however, the value of the crop increases secured by the use of manure is sufficient so that liberal applications of this material should be strongly advocated. Every farmer in the county should see to it that the manure produced on his farm is carefully preserved and returned to the soil if he would secure the best crop yields and keep his soils permanently fertile.

Manure exerts a beneficial effect on soils because of its chemical, physical and bacteriological effects. It contains considerable amounts of plant food constituents which have been removed from the soil by the crops grown and by its use, therefore, the life of the soil is lengthened or in other words, the time is extended before any plant food constituent becomes actually lacking. It improves the physical condition both in heavy clay soils and in light sandy soils. It makes the latter more retentive of moisture, less open and porous and less subject to losses of the valuable constituents by leaching. It opens up heavy soils and makes them better aerated, less impervious, and less retentive of moisture. This means that there will be a greater production of available plant food, as well as better general conditions for the growth of crops. Large numbers of bacteria are contained in manure and these play an important part in making plant food available. The organic matter which manure contains has an important effect, not only on the physical conditions of the soil but also upon the bacterial growth and activities. The organic matter serves as food for bacteria and stimulates their development and this means a further increase in available plant food production. It is quite probable that the bacterial effects of manure are of especial significance on heavy, newly-drained soils which are high in organic matter. Under such conditions the stimulation of available plant food production is particularly necessary and the beneficial effect of manure on such types as the Webster clay loam, silty clay loam and the Bremer soils is undoubtedly due mainly to improved bacterial conditions. In general, however, the beneficial

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effect of manure may not be attributed to any one influence, but is probably due to physical, chemical, and bacterial effects combined.

When compared with commercial fertilizers, it would seem that the application of manure is a very simple and inexpensive operation and the farmer who does not carefully preserve and utilize all the manure produced on his farm is wasting one of his most valuable natural assets. It is difficult to understand why greater care is not taken of this material in order to secure the largest possible effects from its use. In spite of all that has been said about the storage of manure, very frequently it is stored without any care whatever to prevent losses by leaching and weathering, perhaps on a hillside with a slope running down to a stream and the soluble portion of the manure washing away from the farm in large amounts after every rain. Under such conditions the manure will lose 70 to 90 percent of its value and the effect when applied to the soils will be reduced to just the same extent. The farmer may consider manure a waste product to be disposed of with the least possible difficulty, but if he does not prevent losses of valuable portions before applying it to his soils his income from his crops will be reduced in proportion to the decreased value of the manure.

There are many ways in which manure may be stored to prevent losses. A covered yard or a pit may be provided. It may be composted. No one method can be suggested to fit all conditions and in general it may be said that almost any method will be satisfactory provided the manure is kept moist and compact and not exposed to the weather. It may be possible in some instances to apply manure to the soil as produced and thus eliminate the necessity of storage. When this practice can be followed the largest possible effect of the manure is secured on the crop growth, but it is not always practicable to follow this method and in most cases it is necessary to store the manure. If proper care is taken in storing, quite as satisfactory results may be secured from its use as if it were applied directly. It has been estimated that 75 to 80 percent of the plant food removed from the soil by the crops grown may be returned to the land by the use of well preserved manure. If the farmer will care for and utilize manure to the best advantage, he may keep his soils in the best condition of fertility for a long period of years.

The usual application of manure is 8 to 10 tons per acre once in a four-year rotation. In some cases larger applications are made to certain soils, particularly sandy types or for the growth of truck crops. It is not advisable, however, to apply more than 16 to 20 tons per acre for general farm crops. Only for truck crops will larger amounts than this prove profitable. Unfortunately the production of manure on the average livestock farm is not sufficient to permit of large applications to all the soils of the farm and this means that some fields are left without additions of manure. Hence on many farms all the soils cannot be kept up in organic matter by the use of manure and some other material must be utilized. On the grain farm very little manure is produced and here some substitute for farm manure must be employed.

Green manuring is a practice which may be followed as a supplement or substitute for manuring. Leguminous crops are considered the most desirable for use as green manures inasmuch as they are able, when well inoculated, to take

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up nitrogen from the atmosphere and fix it in the soil for the use of subsequent crops. They act, therefore, as a nitrogenous fertilizer while at the same time they keep up the supply of organic matter on both the grain farm and also on the livestock farm. Non-legumes are often used as green manures and in some cases may be of considerable value in that they add to the organic matter content of the soil. They do not add nitrogen, however, and hence they have less value than legumes. When the organic matter content of the soil is low, nitrogen is also low and hence in practically all cases leguminous crops are particularly desirable for use as green manures.

Many legumes are available for use under a wide variety of conditions and it is possible to choose some one legume which will fit in with almost any rotation. Green manuring is a practice, therefore, which may be followed on some livestock farms and must be practiced on grain farms if the supply of organic matter and nitrogen is to be kept up. On the lighter soils in Polk county, and particularly those which show evidence of lack of organic matter by a light color, green manuring may be practiced with profit. It should not be practiced blindly or carelessly, however, for it may bring about undesirable effects if not carried out properly. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The utilization of crop residues, such as straw and stover, is a third means by which the organic matter content of the soil may be kept up. Too often these materials are burned or otherwise destroyed and there is a loss of much valuable organic matter. Such a practice means that the farmer is throwing away material which is of considerable aid in keeping his soils productive. Crop residues may be used for feed or bedding on the livestock farm and returned to the soil with the manure. On the grain farm they may be stored and permitted to decompose partially before application or they may be applied directly. It is particularly important on the grain farm that all residues be returned to the soil but they are also of importance under livestock farming conditions. Crop residues are of value because of their organic matter content and because of their content of plant food constituents. They often increase crop yields to a considerable extent and they constitute a valuable supplement to farm manure and green manures.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Polk county, according to the analyses given earlier in this report, are not very well supplied with phosphorus and, in fact, with one or two exceptions, the supply is rather low. There is no question, therefore, but that phosphorus fertilizers will be needed on the soils of this county in the near future. They would probably be of use, however, in many cases at the present time. The greenhouse experiments which have been reported here and the field experiments in other counties indicate the possibility of value from the application of phosphorus to certain of the major soil types in the county. The field experiments which are now under way in this county will permit of definite conclusions along this line after results have been secured over a period of years. For the present, the only recommendation which can be made is that phosphorus be tested under actual field conditions. Even tho the supply in the soil is sufficient to take care

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of the needs of many crops, there is no assurance that the amount of available phosphorus is sufficient for even one crop. The figures given in the analytical tables in this report show the total phosphorus content of the soils but do not give any indication of the amount which is available. There is no satisfactory method of determining the occurrence of available phosphorus except by testing in the field. It is well known, however, that where the total supply is as low as it is in this county, there is danger of a deficiency in available phosphorus. All the phosphorus which is utilized by plants must be in a soluble available form and even if there is a large total supply, crops may suffer for a lack of phosphorus if the production of the plant food in an available form is too slow. It is quite probable, therefore, that phosphorus fertilizers might yield profitable returns on the soils of this county at the present time and particularly so if the phosphorus which they contain is not being made available as rapidly as it should be.

There are two important phosphorus fertilizers on the market and one of these must generally be selected for use on Iowa soils. The two materials are rock phosphate and acid phosphate. The former is insoluble and must be changed into an available form before it can be of use to plants. The latter is a soluble phosphate and the element is present in it in a form directly utilizable by crops. Acid phosphate, however, costs considerably more than rock phosphate and it contains less phosphorus. It is impossible at the present time to say which of these materials should be used under the different soil conditions existing in Polk county. Field experiments now under way in the county are comparing the value of these two sources of phosphorus. At the present time it is urged that the two materials be tested under actual farm conditions and their relative economic value determined. The material which yields the largest influence at the lowest cost should be considered the most economic material for use. Farmers may test these materials on small areas with little difficulty. Directions for the carrying out of such tests are given in Circular 51 of the Iowa Agricultural Experiment Station and advice along this line may be secured from the Soils Section upon request.

The nitrogen content of the soils of Polk county in some cases is very low while in others the amount of this element is considerable. Only in few cases, however, is there any extremely large supply. In practically all instances, the amount of nitrogen is insufficient to take care of the needs of crops for any extended period of years. It is quite evident that this element must be considered in any system of permanent fertility planned for the soils of the county. The application of farm manures and the return of all crop residues will aid considerably in keeping up the nitrogen content, but they are not sufficient, as has been indicated in a previous section of this report, and the supply of nitrogen will gradually decrease, due to utilization by crops and leaching, if some other means of supplying nitrogen to the soil are not employed.

The utilization of well inoculated legumes as green manures is a most desirable practice for adding nitrogen to soils. Such materials are the cheapest nitrogenous fertilizers which can be used and they have a double value in that they not only supply nitrogen but they also add large amounts of organic matter to the soil. Every rotation should contain a legume and it is very important

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that the legume be thoroly inoculated, as only in this way can the nitrogen of the atmosphere be utilized. The handling of the legume is very important if the soil is to benefit to the largest extent from its growth. A large portion of the crop must be turned under in the soil if its nitrogen content is to be increased materially. If the entire legume crop is harvested for hay, there will be practically no increase in nitrogen content in the soil. If only a part of the crop is harvested and removed and the remainder is turned under in the soil, there may be considerable nitrogen added. If the seed crop only of the legume is removed and the remainder of the crop plowed under, a large amount of nitrogen may be supplied to the soil. The greatest effects, however, are of course secured when the entire legume crop is turned under. The amount of nitrogen added to the soil will depend in this case upon the size of the crop and the efficiency of the inoculation. By the proper growing and handling of legume crops in the rotation, therefore, the nitrogen content of the soils of this county may be built up and kept up. Commercial nitrogenous fertilizers are very expensive and they will not be needed if legumes are utilized according to the plan suggested. Small applications of commercial materials may be used as top dressings to encourage the early growth of certain crops, particularly truck crops, but their use on the soils of this county for general farm crops cannot be recommended. It is highly improbable that they would prove economically profitable. If they are tested on small areas, however, and economic returns are secured, there is no objection to their use.

Analyses made of many of the soils of the state have shown a large supply of potassium and it is very unlikely that this element will be needed on the soils of Polk county for many years to come. The total amount present is so large that there should be no difficulty in securing a proper amount of available potassium to keep crops supplied. If soils are well drained and cultivated and abundantly supplied with organic matter, the production of available potassium should be sufficient in most of the soils of this county for satisfactory crop yields. It is hardly likely, therefore, that potassium fertilizers would prove profitable for use in this county for general farm crops. Small applications as top dressings might be desirable in some cases in order to stimulate early growth. Such materials might be used economically in truck crop growing. There is no objection to the use of potassium fertilizers if they prove profitable, however, and if they are tested on small areas and crop increases secured will warrant their application, they may be applied without injuring the soil.

The use of complete commercial fertilizers is not considered necessary on the soils of this county at the present time. They may be used in truck crop growing and on gardens and prove distinctly profitable, but for general farm crops it is believed that phosphorus fertilizers will prove more profitable. These materials are being tested in the field experiments now under way in the county and the effect on crops from their use is being compared with the effect of various phosphorus fertilizers. Definite comparative data along this line will be available in the future but the indications at present are that the complete brands are less desirable than the phosphorus carriers. If farmers are interested they may readily test any complete fertilizer on a small area on their own farms and determine whether or not the material is profitable for use. It is urged, how-

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ever, that such materials should always be tested in comparison with phosphate fertilizers in order to get an accurate idea of their value and to determine whether phosphorus fertilizers would not prove quite as desirable. There is no objection to the use of complete commercial fertilizers if they prove profitable and particularly if they show greater returns than phosphorus carriers.

LIMING

Many of the surface soils of Polk county are very well supplied with lime and are not in need of applications of this material at the present time. There are a number of types, however, that give an acid reaction and on these types lime should be applied. The Carrington and Shelby soils of the drift uplands and the Tama and Clinton soils of the loessial uplands are all acid. Practically all of the terrace types show acidity, but the bottomland soils are very largely high in lime content, and the Webster soils of the upland are well supplied at present. The lower soil layers are very little different in reaction than the surface soils. Those types which are basic at the surface are basic in the subsoil and the supply of inorganic carbon generally increases in the lower layers. In a few cases where the surface soils are acid, the subsurface and subsoils show a basic reaction but in none of these instances is the supply of inorganic carbon sufficient but that lime will need to be applied in the near future. Hence the indications of lime needs which are given in the surface soils are borne out by the data on the lower soil layers. The figures in the tables given earlier in this report are merely indicative of the needs of these soil types and applications of lime should not be based upon them but upon actual tests on the individual soil. Average figures, even if these figures are the result of many analyses, will not show the exact needs of a soil.

The application of lime to acid soils exerts a beneficial effect on them due to a stimulation of bacterial action and an increase in available plant food production, as well as to the removal of injurious acidity and to a supplying of plant food. Hence the use of lime may bring about increases in crops which are not ordinarily sensitive to acidity. Such increases may be due to the production of more available plant food. Furthermore, if the legume in the rotation is increased in growth by the use of lime, the succeeding crops will be benefited indirectly because of the greater amount of organic matter returned to the soil and because of the addition of nitrogen. This may be considered an indirect effect from the use of lime. It is generally conceded, however, that all crops make their best growth on soils which are not acid and hence it is very desirable that soils be tested for acidity and that lime be applied as needed. It is a profitable practice even if only the legume crop of the rotation is considered but when the other crops are increased also, the value of lime is very great.

The farmers of Polk county should test their soils and determine the lime needs. They may do this themselves or they may send samples to the Soils Section of the Iowa Agricultural Experiment Station and have them tested free of charge. Furthermore, they should see to it that their soils are tested regularly at least once in a four-year rotation. One application of lime to a soil is not sufficient, as lime is removed from soils continually thru leaching and utilization by crops. The most desirable practice is to test the soil before the clover

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crop or other legume of the rotation is seeded and apply the necessary lime preceding that crop. The largest effect from the use of the material will be secured in this way and satisfactory growth will be secured. Further information regarding the use of lime and sources from which the material may be secured are given in Bulletin 151 and Circular 58 of the Iowa Agricultural Experiment Station.

THE ROTATION OF CROPS

The natural fertility of soils is gradually reduced thru the growth of crops but the reduction is much more rapid where any one crop is grown continuously. Not only is the fertility of the soil decreased, but the actual income from the land and the value of the land is reduced. It has often been believed that the growing of a certain crop continuously would provide a larger income from the land than the use of a rotation containing crops of less money value. This assumption is incorrect, however, even if the crop grown continuously has a higher market value than the other crops used in the rotation. The value of all the crops grown over a period of years will be greater where a rotation is followed.

No rotation experiments have been carried out in Polk county, but there are several rotations which have been followed in the county and in other parts of the state with satisfactory results. These rotations are suggested below and any of them may be used in this county. Variations in these rotations may be made as desirable and in fact almost any rotation may be employed provided it contains a legume and the most profitable crops.

I. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy).
Fourth Year—Clover. (If timothy was seeded with the clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain).
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

DRAINAGE

The natural drainage system of Polk county is fairly adequate, but there are considerable areas in the central portion of the county between the Skunk river and the Des Moines river where drainage is poor and the installation of tile is very necessary for the most satisfactory crop production. There are also small areas in the western part of the county near Grimes where tiling is very desirable. These areas are mapped as Webster clay loam and Webster silty clay loam and it may be said that in general where these types occur, drainage is poor.

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There are smaller areas of terrace and bottomland types which are likewise poorly drained. The soils of the Bremer series of the Wabash and Lamoure series are all in need of drainage. In the case of the Wabash and Lamoure types, as they are on the bottoms, they are of course subject to overflow and are not only in need of drainage, but of protection from overflow.

In general it may be said that the Webster and Bremer soils of the county are chiefly in need of drainage in order to make them satisfactorily productive. No other treatment will prove of value on these soil types until they are adequately tiled out and when this is done very satisfactory crop yields may be secured, as the soils are naturally highly productive. The installation of tile may be rather expensive, but the returns secured more than warrant the outlay. The experience of many farmers confirms this conclusion and proves that proper drainage may mean the difference between very satisfactory crops and no crop at all.

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not likely to be subject to erosion, while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

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There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but it is less harmful and is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Polk county erosion occurs to a considerable extent in the areas of Lindley fine sandy loam, Shelby loam and Clinton silt loam. In some instances serious washing has occurred in some of the other soil types, particularly the Carrington loam and the Tama silt loam, and wherever any removal of surface soil thru this destructive action occurs, some means of control should be adopted.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of staking in is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways, but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

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Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

"Staking In." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfacion is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed up stream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point down stream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It

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will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters, and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey Dam. In fact the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too closely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of

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erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water-absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

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Trees. Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features, it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil

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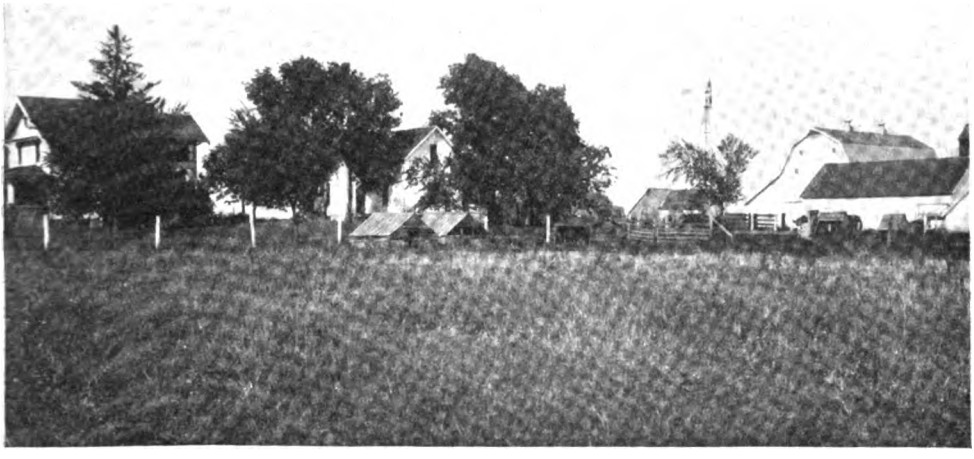

Fig. 6 A Polk county farmstead on Carrington loam.

thereby reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN POLK COUNTY*

There are 31 soil types in Polk county, a shallow phase of the Carrington loam, a shallow phase of the Tama silt loam and areas of riverwash and muck and peat, making a total of 35 separate soil areas. They are divided into four large groups according to their origin and location and these groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are six drift soils in the county belonging in the Carrington, Webster, Lindley and Shelby series and these, with the shallow phase of the Carrington loam, make seven soil areas. The area covered by this group of soils amounts to 60.1 percent of the total area of the county.

CARRINGTON LOAM (1)

The Carrington loam is the most extensive drift soil in the county and it is the largest individual type. Together with the shallow phase, which is minor in area, it covers 32.9 percent of the total area of the county. It occurs chiefly along the drainageways of the county, altho there are many smaller bodies of it occurring on the uplands of the flatter regions. The largest continuous area broken only by narrow strips of bottomland extends across the county from Mitchellville thru Des Moines to the western boundary of the county. This area marks the edge of the drift soils of the county, the area to the south

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

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being covered by loess types. Rather considerable areas of Carrington are found south of the Des Moines river around Grimes, and in the northeastern part of the county on the uplands between Indian creek and Skunk river. The type is also developed to some extent in the northwestern part of the county along Big creek. There are numerous small areas in all parts of the county north of Des Moines but in general the areas mentioned are the most important.

The surface soil of the Carrington loam is a dark brown mellow loam extending to a depth of 12 inches. At that point the soil becomes a brown to dark yellowish-brown heavy loam. At 18 to 20 inches the subsoil is encountered and this is a yellowish-brown to brownish-yellow somewhat gritty silty clay loam to clay. Occasionally boulders occur on the surface and thruout the soil section and glacial pebbles are not uncommon. The surface soil of the type along the east county line near Farrar, along the west county line near Granger (in Dallas county) and near Campbell is shallower than typical, averaging 8 to 10 inches and the organic matter content is lower, the color somewhat lighter and the sand content higher. In these areas the texture is almost a fine sandy loam. There are small areas on the sharper slopes which have a grayish cast in the lower subsoil and contain a small amount of lime. These areas occur mainly in the territory adjoining the loess soils in the southern part of the county. These small areas really belong in the Clarion series but owing to their small extent they have not been separated out in the county. In the northern part of the county on some of the smaller knolls, the subsoil of the type occasionally becomes quite sandy. When adjoining the Webster series, the surface soil of the type seems to be somewhat higher in organic matter supply and clay content, but the line of division between the Carrington and Webster soils is usually rather sharply defined. When the type is associated with silt loams and especially with the Tama silt loam, the surface soil is somewhat shallow and the subsoil is a reddish-brown gritty clay.

In topography the Carrington loam is strongly undulating to gently rolling and in general it is adequately drained. In some of the smaller flat areas in the central portion of the county where the type is associated with the Webster soils, artificial drainage has often proven of value.

Probably 80 percent of the Carrington loam in the county is under cultivation, some of the more rolling areas being kept in pasture. The forest growth which occurred in the more rolling territory was composed mainly of oak, ash, elm, hickory, locust, hackberry and wild cherry with undergrowth of hazel and buck brush. The original native grasses have been largely replaced by bluegrass on the pasture areas. In the cultivated portion corn is the most important crop grown and yields on the average 35 to 40 bushels per acre. Oats and wheat are of secondary importance, oats yielding 35 to 45 bushels, winter wheat 18 to 25 bushels and spring wheat 18 to 20 bushels. Winter wheat is grown more commonly than the spring varieties, altho the latter are increasing in favor. Clover and timothy are the most important hay crops and yields of 1½ to 1¾ tons per acre are secured. Clover alone is grown to some extent, yielding one to two tons per acre. Timothy alone is also grown somewhat, yielding one to 1½ tons per acre. Some native hay is cut on the more rolling areas. Alfalfa is produced successfully under favorable seasonal conditions and yields of 2½

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to 3 tons per acre have been secured. In the southern part of the county apples, berries and grapes have been grown on this soil with good results. Some trucking is carried on in the vicinity of Des Moines. Sweet corn is produced to some extent for the canning factories and yields 2½ to 3 tons on the average. Pumpkins are grown quite extensively, producing at the rate of 3 tons per acre.

The needs of the Carrington loam for greater crop growth include the use of lime, the application of manure and probably also the addition of phosphorus fertilizers. The type is practically always acid in reaction and hence it should be tested and lime applied as shown to be necessary according to the tests, if the best growth of legumes and of farm crops in general is to be secured. The soils are not particularly well supplied with organic matter and applications of farm manure bring about large increases in crop growth. Where farm manure is not available or the amount is not sufficient to keep all the soils of the farm supplied, proper utilization of the legume crop of the rotation should be practiced in order to increase and maintain the organic matter and nitrogen content of the soil. Preliminary tests have indicated that phosphorus fertilizers may be of value on this type and while the results are not sufficiently complete at the present time to permit of definite conclusions, it is urged that phosphorus fertilizers be tested in the field on small areas and in this way the need of this element may be determined. Acid phosphate and rock phosphate may be employed in such tests and thus it will be possible to determine which of these materials will yield the most profitable returns. Complete commercial fertilizers are not recommended for use on this soil at the present time, altho there is no objection to their use if they prove of value. Tests of such materials should be made in comparison with phosphorus fertilizers, as it is generally believed that the latter materials will prove of more economic value than the complete brands. The type is usually very satisfactorily drained but in the few instances where drainage is poor, tiling could be practiced. There is very little erosion of this type except in a few areas where the topography is more steeply rolling than typical.

CARRINGTON LOAM—SHALLOW PHASE (142)

The shallow phase of the Carrington loam is of minor importance in the county, covering less than one percent of the total area. It occurs in small irregular shaped areas in various parts of the county, usually on the rolling slopes to the larger creek valleys. A few areas are found on the gentle slopes and near the heads of drainageways. The type is, of course, the result of erosion or the washing away of surface soil.

The surface soil of this shallow phase of the Carrington is usually about six inches in depth. It is lighter colored than the typical soil and the subsoil, which is frequently plowed up, is a brown to yellowish-brown silty clay loam, grading into a grayish-yellow silty clay loam in the lower depths and particularly on some of the steeper slopes. Boulders and pebbles are common in the subsoil. This soil differs from the Shelby loam in that it has a more compact subsoil and contains a smaller percentage of gravel.

Most of the soil is used for pasture, as it is too rolling for profitable cultivation, the topography being generally steeply rolling. On the pastured areas native

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prairie grasses are found, with some forest trees, chiefly oak, elm, hickory and hazelnut. On the less rolling areas, the land is sometimes cultivated along with the surrounding soils but the yields of general farm crops are less satisfactory than on the typical Carrington.

The needs of this soil are first of all, for protection from washing or erosion and then for the addition of organic matter. There are some areas where the soil should undoubtedly be kept in permanent grass or pasture in order to prevent the excessive washing. Additions of farm manure and the growing and turning under of green manure crops would be very desirable where cultivated crops are to be grown. The soil is acid and in need of lime. It would probably also respond to phosphorus fertilizers.

WEBSTER CLAY LOAM (56)

The Webster clay loam is the second largest drift soil and the second largest type in the county, covering 17.0 percent of the total area. It occurs generally on the uplands in the flatter portions of the north three-fourths of the county. The largest areas of the type occur between the Skunk river and Four Mile creek and between Four Mile creek and the Des Moines river, from Mitchellville north thru Elkhart and from Oralabor north to Sheldahl. It is found generally on the gentle slopes and flatter uplands, with the Carrington loam separating it from the streams. Some areas occur, however, on long gentle slopes extending to the drainageways. It is associated very closely with the Webster silty clay loam, this type occurring in the lower flat areas which are particularly poorly drained. In the area northeast of the Skunk and in the southwestern part of the county, the type is found on the flat level upland areas.

The surface soil of the Webster clay loam is a very dark brown or nearly black clay loam 15 inches in depth. It is underlaid by a dark yellowish-brown rather compact clay loam which at about 24 inches becomes a yellowish-gray or grayish-yellow gritty clay loam or clay. Where the type joins lighter textured soils, the surface two to four inches may be quite loamy. Glacial boulders and gravel occur occasionally on the surface and thru the soil section. The lower subsoil is usually high in lime content and frequently the upper soil layers will contain lime. Reddish-brown iron stains are usually found in the subsoil of this type.

In topography the Webster clay loam is almost flat to very gently undulating and the drainage is poor. The installation of tile has been made in many areas and has proven very desirable for this type. In fact, when well drained, the soil is one of the most productive in the county. It is practically all under cultivation and the important crops grown are corn, oats, hay and wheat. Corn yields 40 to 50 bushels per acre and in favorable seasons yields may run very much higher. Oats yield 30 to 40 bushels per acre and winter wheat 18 to 23 bushels per acre. Little barley or spring wheat are grown. Timothy and clover mixed yield about two tons of hay per acre, red clover alone 1¾ to 2 tons and timothy alone 1¼ to 1¾ tons. Alfalfa is grown on small areas and satisfactory crops are secured. Near Altoona, Grimes and Maxwell, sweet corn and pumpkins are grown for the canning factories, average yields of the former amounting to three to five tons per acre and of the pumpkins, three tons per acre.

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The Webster clay loam is a very productive soil and, when properly handled, very satisfactory crop yields may be secured. In the first place it should be thoroly drained by the installation of tile. When this is accomplished the soil must be properly cultivated. It should not be plowed when too wet, as it forms clods and becomes difficult to work down into a good tilth. In dry seasons it may bake and crack. Additions of small amounts of farm manure are quite desirable on this soil in spite of the fact that it is high in organic matter content. It is particularly desirable when the soil is newly drained, that an application of manure be made in order to stimulate the production of available plant food. If the surface soil is acid, lime should be applied in order to secure the best growth of legumes. In most cases, however, this material is not needed. The addition of phosphorus fertilizers may prove of value on this type and tests of acid phosphate and rock phosphate are recommended.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the third largest drift soil in the county and the fourth largest soil type in the county, covering 4.4 percent of the total area. It occurs mainly thruout the central portion of the county between Skunk river and the Des Moines river in association with the Webster clay loam. The areas of this type are usually surrounded by the Webster clay loam. In some instances the type is associated with the Carrington loam, occupying narrow strips in the lowest portions of the depressions along sluggish drainageways or occurring as larger irregular areas, giving the appearance of having formerly been shallow ponds or marshes. The largest areas occur in the vicinity of Bondurant and northwest of Ankeny.

The surface soil of the Webster silty clay loam is very dark brown to nearly black in color and extends to a depth of about 18 inches. This is underlaid by a dark brown to dark drab clay which at about 24 inches grades into a yellowish-gray or grayish-yellow clay loam or clay. The subsoil shows many reddish-brown iron stains and contains numerous lime concretions. Both soil and subsoil are highly calcareous. In some of the lake-like depressions the surface soil to a depth of three to five inches may be quite peaty. Clay spots occur in the center of a few areas and where surrounded by the Carrington soils, the surface soil may be loamy in texture. This type is darker colored than the clay loam, contains more silt in the surface soil and occurs in more depressed areas. When wet it is very sticky but does not crack as badly as the clay loam, upon drying, owing to its higher content of organic matter. Strips of soil of this type occurring around small pond-like depressions frequently contain so-called "alkali salts" to such a large extent that crops are injured. Only small narrow areas of the type are affected in this way and frequently the alkali does not appear until after the area has been drained. The removal of the excess salts in such areas should be accomplished by the installation of tile thru the alkali spot and thru the liberal application of horse manure.

In topography the Webster silty clay loam is nearly level to depressed, and drainage is naturally very poor. Water may stand on the surface of undrained areas for long periods following heavy rains. The type must be thoroly ditched and tile drained in order to make it properly productive. Considerable areas

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of this type have been kept in native grasses, especially in the larger areas and where water remains for long periods after rains. On such areas there is a large growth of slough grasses and bluegrass which are either used for pasturage or hay. A considerable portion of the soil is cultivated along with the clay loam and crop yields on properly drained areas frequently surpass those obtained on the clay loam. In wet seasons small grains are apt to lodge badly and cultivation is difficult.

This type is primarily in need of drainage to make it satisfactorily productive. When this is accomplished large crop yields will ordinarily be secured. It is high in organic matter and nitrogen and is not in need of lime. The phosphorus content is not high and this element may be needed in the near future. It is possible that applications of phosphorus fertilizers might prove of value in some cases now. Small applications of manure might be of use on newly drained areas, but should not be applied preceding the growth of small grains. Where alkali conditions occur in this type, proper installation of tile is the first operation needed and this should be followed by a liberal application of manure or by the turning under of a green crop, which will aid in the removal of the large amount of salts causing the alkali condition.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county covering 2.5 percent of the total area. It occurs chiefly on smooth and rather gradual slopes to the north of the Des Moines river and along the Skunk river, Indian creek, Big creek and Little Beaver creek. The largest continuous area occurs northeast of the Skunk river. Rather considerable areas are also found along the Des Moines river in the vicinity of Des Moines and in the area about Polk City.

The surface soil of the Carrington fine sandy loam is a dark brown to dark grayish-brown in color. At about 15 inches this passes into a brown to yellowish-brown fine sandy loam which sometimes changes to a loamy fine sand or fine sand in the lower part of the three foot section. In some areas the organic matter has been removed to a considerable extent and the surface soil is a grayish-brown in color when dry. When associated with the heavier soils, the surface soil may be quite loamy and the subsoil a heavy loam or light silty clay loam. Very few glacial boulders and little gravel is found.

In topography this type is rolling to steeply rolling, and it is well drained. In areas with the lighter textured subsoil, drainage may be excessive and crops may suffer during periods of drouth. About 60 percent of the soil is under cultivation, the remainder being used for pasture. Corn, oats and wheat are the principal crops grown. Near Des Moines watermelons, cantaloupes, sweet potatoes and other truck crops and small fruits are grown satisfactorily. Some of the areas are too steeply rolling to permit of satisfactory cultivation and these areas should undoubtedly be kept in permanent pasture.

This soil may give very satisfactory yields of general farm crops in seasons of normal rainfall. Frequently crop yields are quite as large as on the Carrington loam but dry weather usually reduces the yields considerably. The soil is low in organic matter and nitrogen and applications of farm manure are very desirable. Large amounts of this material should be used in order to make the

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soil more productive and to reduce the danger of crop injury from drouth. The utilization of manure is especially important on the areas where truck crops are grown. In case farm manure is not available in sufficient amounts, leguminous crops should be utilized as green manures in order to build up the soil in organic matter and nitrogen. The soil is acid in reaction and should receive applications of lime in order to secure the best growth of legumes. The phosphorus supply is low and applications of phosphorus fertilizers should probably be made at the present time and will undoubtedly be needed in the future. Where truck crops are grown, the application of commercial fertilizers may be of considerable value and special brands desirable for use in the growing of certain crops may be employed with profit.

LINDLEY FINE SANDY LOAM (136)

This is a minor type in the county, covering 1.9 percent of the total area. Practically all of it occurs along the Des Moines river, the largest bodies being found west of the river in the vicinity of Camp Dodge and northwest of Polk. Areas of the type are also found in the vicinity of Des Moines and along the Raccoon river, Walnut creek and Four Mile creek.

The surface soil of this type is a grayish-brown fine sandy loam extending to a depth of about ten inches. Below this point it is a gray and brown mottled compact silty clay loam to a depth of 24 inches, then passing into a brown to yellowish-brown very compact gritty clay. Below the three foot section the material is a yellowish-brown, gritty, friable clay, mottled with gray spots which consist of calcareous material. The surface soil contains considerable very fine sand and on the flatter areas may be a very fine sandy loam. Numerous reddish-brown iron stains occur in the subsoil. A few glacial boulders occur and considerable coarse sand and gravel is found in the lower subsoil. Within this type there are included small areas of soils that are not typical. Along the steeper slopes of the Des Moines river and south of the city of Des Moines, there are exposures of drift material, mixed with silt, that are not typical. The surface material in these areas is usually a reddish-brown boulder clay, coarse sand, buff colored silt and gray sticky clay, or a mixture of all of these. The surface of these areas is almost perpendicular and they are included owing to their small extent and to the fact that they are of little value.

In topography this type is rolling to steep. It is usually found on steep slopes, altho in some places it extends over narrow rather flat divides. Where the topography is steep, the drainage is excessive and erosion has been very active, causing the formation of numerous ravines. The smoother areas are adequately drained.

Less than half of the Lindley fine sandy loam is under cultivation. It was originally a timber soil and much of it still supports a growth of oak, elm, wild cherry, hickory, hazelnut and buck brush. These areas are utilized as pasture for cattle and horses. The cultivated portion is utilized for the same crops as the Carrington fine sandy loam. Near Des Moines the type is used for the raising of truck crops.

Yields are somewhat less on this soil than on the Carrington fine sandy loam. The type is particularly in need of organic matter and should receive liberal

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applications of farm manure. Where truck crops are grown, the addition of especially large amounts of this material is very desirable. If farm manure cannot be employed, leguminous crops should be utilized as green manures. Erosion may be very active in this type and some method of preventing this injurious action should be practiced if the soil is to be cultivated. It is often in need of lime and should be tested for acidity before attempting to grow leguminous crops. The phosphorus content is low and for the growth of general farm crops, phosphorus fertilizers would probably prove of value. Applications of special fertilizing materials might be of use in the growing of truck crops.

SHELBY LOAM (79)

The Shelby loam is a minor type in the county, covering 1.4 percent of the total area. It occurs in numerous small areas chiefly along the Des Moines river. There are small areas, however, thruout the northern part of the county along Four Mile creek, White Oak creek, Beaver creek and Walnut creek. Still smaller spots of this type are found along the smaller tributaries to these streams and scattered thru the Carrington upland. The larger areas usually occur in irregular strips along the streams mentioned.

The surface soil of the Shelby loam is dark brown to black in color and extends to a depth of 8 to 10 inches. The subsoil is a brown to yellowish-brown rather compact heavy loam to silty clay loam. Below 18 to 24 inches this passes into a brownish-yellow to grayish-yellow rather loose silty clay loam or sandy clay. Glacial boulders and gravel occur thruout the soil and subsoil. In the lower layers there are occasionally calcareous or lime spots and in many places the subsoil shows reddish-brown iron stains. In some of the areas on narrow ridges or knolls a layer of coarse sand and gravel is found at varying depths below the surface soil. This is the usual condition in small areas in the northern part of the county and along the west county line. On the flatter areas the soil may be almost black in color, while in the rougher topographic position it is rather light colored. Frequently the surface soil is light textured and approaches a fine sandy loam.

In topography this soil is rolling to steeply rolling. Along the river it occurs in abrupt slopes which have been eroded and contain numerous deep ravines. In the smaller areas and those at some distance from streams, the topography is ridgy or knolly and in the north central part of the county the knolls of the type rising above the Webster soils may be almost flat. In the rougher areas drainage may be excessive and in general it is entirely adequate.

Probably less than a third of this type is under cultivation, oats, corn and wheat being the principal crops grown. Corn yields 25 to 35 bushels per acre, oats 45 to 50, and fair yields of wheat are secured. Sweet corn gives 2 to 2½ tons of green ears per acre. On the more rolling areas, cultivation is almost impossible and these areas are kept in native grasses and are used for pasture. Practically all of the areas along the streams were originally forested.

On the rougher portions of the type cultivated crops should not be grown owing to the fact that the plowing up of the sod in such locations leads to very serious erosion. Such areas should undoubtedly be kept in pasture. On areas which are suitable for cultivation fairly satisfactory crop yields may be secured

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in favorable seasons. Methods of preventing erosion should be practiced in all cases. The soil is low in organic matter and should receive liberal applications of farm manure. Leguminous crops may be used as green manures with profit. The type is acid and in need of lime. The phosphorus supply is low and applications of phosphorus fertilizers would probably be of value now and will certainly be needed in the near future.

LOESS SOILS

There are three loess soils in the county and these, with the shallow phase of the Tama silt loam, make a total of four loess soils. They are classed in the Tama and Clinton series and the total area covered by this group of soils amounts to 14.5 percent of the county.

TAMA SILT LOAM (120)

The Tama silt loam is the most extensive loess type in the county and it is the third largest individual soil type. Together with the shallow phase, which is minor in area, it covers 11.1 percent of the total area of the county. It occurs on the uplands in the southern part of the county, being the chief upland type in that section of the county. Practically all of it occurs in three large areas which are separated by Camp creek, Mud creek and the Des Moines river. There is also a small area north of the Raccoon river in the southwestern corner of the county.

The surface soil of the Tama silt loam is a dark grayish-brown to dark brown smooth silt loam extending to a depth of 12 or 14 inches. The subsoil is a dark yellowish-brown, heavy silt loam, grading at about 22 inches into a friable brownish-yellow light silty clay loam. Reddish-brown iron stains occur thruout the lower subsoil. The surface soil is somewhat lighter colored on the slopes, while on the divides it is deeper and darker in color. Where the surface soil is six inches or less in depth, the shallow phase has been mapped. The type is

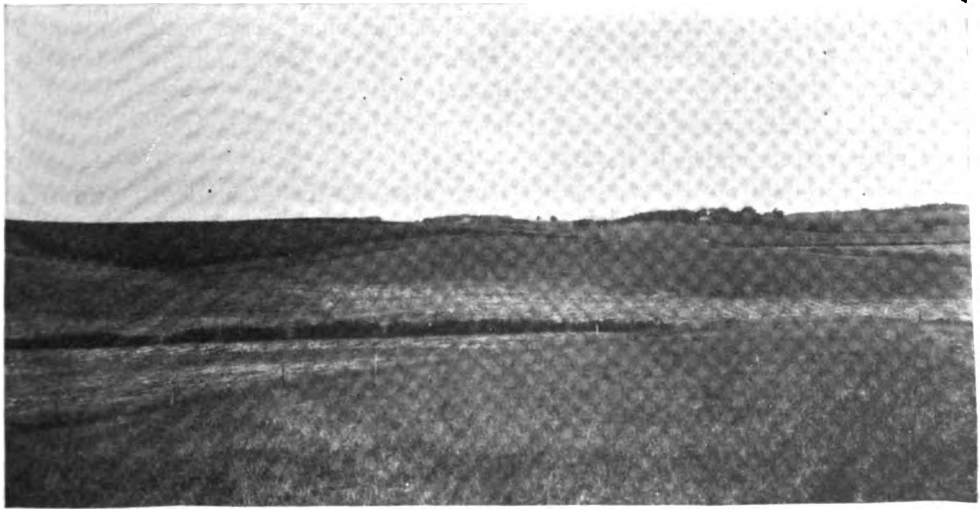

Fig. 7. Topography of Tama silt loam.

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associated with the Clinton silt loam and in many cases the boundary between these two types is rather arbitrarily established, owing to the fact that there is a gradual transition from the darker colored Tama to the lighter colored Clinton.

In topography the soil is smooth to rolling. The divides are narrow and smooth and the valleys V-shaped. Along the streams the topography is more rolling. Drainage is adequate over most of the type, altho there are a few small areas along the more sluggish streams where tiling would be of value.

The Tama silt loam is nearly all under cultivation and the leading crops grown are corn, wheat and oats. Corn yields 30 to 40 bushels per acre, oats 45 to 50 bushels, winter wheat 20 to 27 bushels and spring wheat 18 to 22 bushels. Considerable hay is grown and red clover and timothy mixed yield 2 tons per acre, clover alone 1¾ to 2½ tons, timothy alone 1¼ to 1¾ tons and alfalfa 2½ to 3 tons per acre. Apples and grapes are grown to some extent. Blackberries, raspberries, strawberries, cabbage, beets, potatoes, beans and onions are grown on some of the areas south of Des Moines.

This type is rather productive and in general crop yields are fairly satisfactory. It is not particularly high in organic matter, however, and applications of farm manure are of considerable value. This material should be used in liberal amounts where truck crops are to be grown. Leguminous green manure crops might be employed in some cases to advantage. The soil is acid and in need of lime, especially for the growth of legumes. It is much better supplied with phosphorus than any of the types in the county, but applications of phosphorus fertilizers might prove of value even at the present time and certainly will be needed in the future. Where truck crops are grown the application of special fertilizer brands would probably prove profitable.

TAMA SILT LOAM—SHALLOW PHASE (143)

The shallow phase of the Tama silt loam is minor in area, covering 1.2 per cent of the total area of the county. It occurs chiefly along the Des Moines river and the Raccoon river, the largest area being found south of the Raccoon river and occupied by the city of Des Moines. Other small areas occur along the heads of small drainageways or on very narrow divides in the more rolling topography. It is found in association with the Tama silt loam of the upland on the rougher areas where erosion has been active and considerable portions of the loess have been washed away.

The surface soil of the type is not more than six inches in depth and is in general dark brown in color. Frequently, however, it is a dark yellowish-brown to dark grayish-brown, due to an admixture of the yellowish-brown subsoil.

In topography this phase is rolling to strongly rolling and drainage is in places excessive. About one-fourth of the total area of the type is occupied by the city of Des Moines, and of the remainder, about 60 percent is under cultivation. It is utilized for the same crops that are grown on the typical Tama. The balance is utilized for pasture and supports a growth of prairie grasses and bluegrass, with some forest trees.

The soil on the cultivated areas is somewhat less productive than the typical Tama owing to the fact that it is shallow. It is in need of applications of organic

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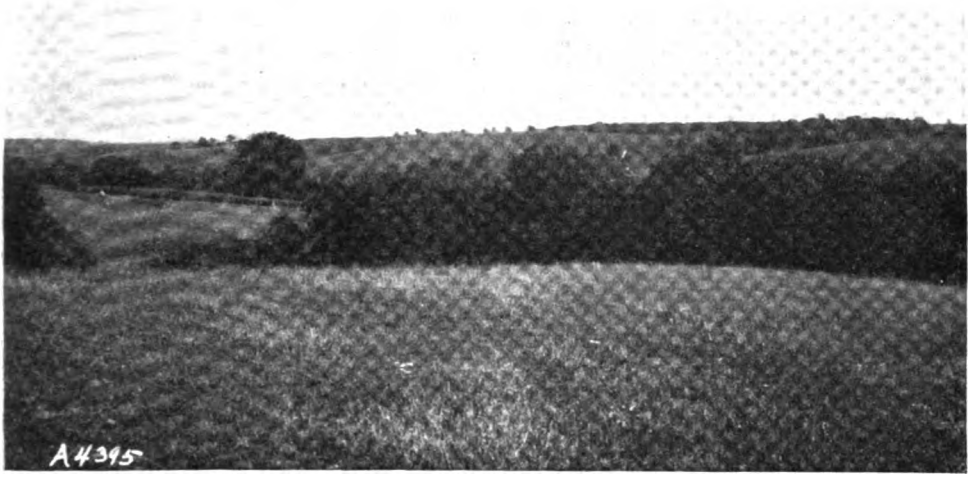

Fig 8. Clinton silt loam is rolling in topography, and drainage is good.

matter and liberal amounts of farm manure should be applied. Leguminous green manures might also be used with value. It is acid and in need of lime and applications of phosphorus fertilizers would undoubtedly prove of value. In the cultivated portion it is very important that precautions be taken to prevent erosion and some of the areas should undoubtedly be kept in permanent pasture.

CLINTON SILT LOAM (80)

The Clinton silt loam is the second largest loess type in the county, covering 3.3 percent of the total area. It occurs in the southern tier of townships across the county along the Des Moines and Raccoon rivers and is associated with the Tama silt loam of the upland. The largest area occurs in Four Mile township southeast of Des Moines. Another considerable area is found along Camp creek in the southeastern corner of the county. Smaller areas occur along the Raccoon river and the various tributaries to this stream.

The surface soil of the Clinton silt loam is a brown to light brown or grayish-brown smooth silt loam extending to a depth of about seven inches. The subsoil is a mottled brown or brownish-yellow and gray heavy silt loam passing at about 18 inches into a brownish-yellow or yellowish-brown very compact clay. Occasionally the brown and gray mottling may continue thru the lower subsoil. In places on the slopes some smooth very fine sand may occur in the surface soil. In uncleared areas the organic matter content in the surface soil may be somewhat higher than the typical and the color a little darker.

In topography this type is rolling and drainage is good. Excessive washing occurs on some of the steeper slopes. About one-half of the type is used for pasture and a large portion of this is occupied by forest trees. The less rolling areas are nearly all under cultivation with wheat, corn and oats the principal crops

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grown. Winter wheat yields 18 to 25 bushels per acre, oats 35 to 40 bushels and corn 20 to 30 bushels. Fruit growing and trucking are important industries near Hastie and there are several small commercial orchards in this locality. Apples and grapes do well when properly handled. Potatoes produce satisfactory yields when the organic matter supply is sufficient.

This soil is somewhat less productive than the Tama soils owing largely to its lower content of organic matter. Its chief need is for applications of farm manure and if this is not available, the use of leguminous green manures would prove profitable. It is acid in reaction and should be limed. It is low in phosphorus and applications of phosphorus fertilizers would be of value for the growth of cultivated crops. On some of the rougher portions the soil should undoubtedly be left in pasture and on many of the areas under cultivation protection from erosion is very necessary if satisfactory crop yields are to be secured and the soil kept from serious washing.

TAMA LOAMY FINE SAND (145)

This is a very minor type in the county, covering only 0.1 percent of the total area. It is developed in small areas along the Raccoon river and some of the minor drainage channels in the southwestern part of the county and almost entirely within Bloomfield township.

The surface soil of the type is a dark grayish-brown loamy fine sand underlaid at about 15 inches by a lighter colored loamy fine sand or fine sand. In the areas joining the other uplands the surface soil may be somewhat heavier than the typical. It occurs on the slopes to drainageways and drainage is usually excessive.

Most of the type is used for pasture. Corn, wheat and oats are grown to some extent but the yields of these crops are rather low, particularly in dry seasons. Watermelons, cantaloupes and cucumbers grow well on the soil when it has received liberal applications of manure. This type is particularly in need of organic matter if it is to be cultivated and farm manure should be used as far as possible and if this material is not available, leguminous crops should be used as green manures. With a proper supply of organic matter in the soil, crops will not be so subject to injury from drouth. The soil is acid and in need of lime. The phosphorus content is low and phosphorus fertilizers would be necessary for the best growth of crops. Special brands of fertilizers may probably be used to advantage where truck crops are to be grown.

TERRACE SOILS

There are eleven terrace types in the county, classified in the Waukesha, Bremer, O'Neill, Buckner and Chariton series. The terrace types together cover 11.4 percent of the total area of the county.

WAUKESHA LOAM (60)

The Waukesha loam is the largest individual terrace type in the county, covering 3.7 percent of the total area. It occurs in all parts of the county on narrow terraces along the various streams. The largest areas are found in the vicinity of Camp Dodge, along Beaver creek and near Des Moines along the Des Moines river, a large part of the city being located on this type. Other

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considerable areas occur in the northeastern part of the county along Indian creek and Skunk river. Small areas are found along many of the other streams of the county.

The surface soil of the Waukesha loam is a dark brown friable loam extending to a depth of about 15 inches. This is underlaid by a brown heavy loam which passes into a brown to yellowish-brown or brownish-yellow friable silty clay loam. On the more level areas the surface soil of the type is rather dark in color, while on the slopes it becomes lighter than the typical. Ocassionally glacial gravel or pebbles are found in the soil section. In the southern part of the county the loam is derived mainly from the loess of the uplands. The subsoil is in general rather compact in structure, but in the areas north of the Skunk river and west to Beaver creek, the subsoil is open and very friable. In the latter location there are small areas where the soil somewhat resembles the Shelby loam. These areas are very minor in extent. In the area along the Story county line in the northeastern corner of the county, the surface soil is heavier than typical, approaching a silty clay loam. The subsoil is a dark yellowish-brown silty clay loam which becomes lighter in color and more compact at the lower depths.

In topography this soil varies from flat to gently undulating or sloping. Along the smaller creeks it lies from 5 to 10 feet above the first bottoms. Along the larger creeks and rivers it may lie as high as 40 feet above the overflow land. The type in general is very satisfactorily drained and the subsoil conditions are such that it is not drouthy.

About 80 percent of the Waukesha loam is under cultivation, a small proportion being occupied by towns and farmsteads or used for pasture. The most important grain crops are corn, oats and wheat. Corn yields 35 to 40 bushels per acre, oats 35 to 45 bushels, winter wheat 20 to 27 bushels and spring wheat 18 to 21 bushels. Hay is grown to some extent and clover and timothy mixed produce 1½ tons per acre, clover alone 1½ to 1¾ tons and timothy alone 1¼ to 1½ tons. Alfalfa has been grown to some extent on the type and gives very satisfactory yields. Some sweet corn is grown in the northeastern part of the county and sold to the canning factories.

The Waukesha loam is rather a productive type and crop yields are fairly satisfactory. They may be increased, however, by proper soil treatments. The soil will respond to applications of manure and all the manure produced on the farm should be carefully stored and returned to the land. If manure is not produced in sufficient amounts, leguminous crops should be used as green manures. The soil is acid and in need of lime and this material should be used if the best growth of legumes is to be secured. Applications of phosphorus fertilizers may be needed in the future and tests of these materials are urged at the present time.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a minor terrace type, covering 1.8 percent of the total area of the county. It occurs along the bottomlands of the Skunk river, the Des Moines river and the Raccoon river in rather extensive areas. Smaller narrow strips are found along the bottoms of some of the minor streams of the county. The largest area of the type is along the Des Moines river south

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and east of Des Moines. Another rather extensive area is found along the Raccoon river, the city of Valley Junction being very largely located on this type. A third area which is rather extensive is found along the Skunk river in the northeastern part of the county.

The surface soil of the Bremer silty clay loam is a dark brown to nearly black silty clay loam. This grades at about 18 inches into a dark brown to dark brownish-gray rather tough clay. Numerous rusty brown iron stains are found in the subsoil. Small spots of the loam occur within these silty clay loam areas, but they cannot be shown on the map because of their small extent. The boundary lines between this type and the silt loam and loam of the same series are rather arbitrarily drawn, as there is usually a gradation from one type to the other. In areas adjoining the Bremer clay and where the soil is poorly drained, there is a higher clay content and the subsoil may be a nearly black dense clay. This is true in the areas west of the Skunk river. In the areas near Loring the lower subsoil is brownish-gray to drab in color. Occasionally in the same areas in this locality in the higher-lying parts of the type, the lower subsoil may be a brown to brownish-yellow or grayish-yellow clay. Along the smaller streams there may be some gravel in the lower subsoil and in a few small areas along Beaver creek, the lower subsoil has a yellowish to grayish cast and lime occurs thruout the soil section. In these areas the soil really should be in the Fargo series but is not separated owing to its small extent. In the area along Indian creek in the northeastern part of the county, the soil is underlaid at about thirty inches by a layer of coarse sand and gravel.

In topography the Bremer silty clay loam is nearly level, in some cases sloping very gently toward the streams. Practically all of it is above ordinary floods but occasionally there are areas which are said to have been overflowed once or twice during the past forty years. Along the Des Moines river the terrace level is 10 to 15 feet above the present stream bed. Along the Skunk river and bordering the creeks it is 2 to 10 feet above overflow land. Drainage of the type is fair but on the more level areas water may stand for considerable time following heavy rains. The installation of tile has proven of advantage in many cases in handling this soil.

The Bremer silty clay loam is practically all under cultivation except for the land occupied by farmsteads and towns and a very few small pastures. The most important crops are corn, oats, wheat and hay. The yields of these crops are very much the same as on the Carrington loam, the hay crops frequently giving much higher yields than the grain crops. This soil is particularly in need of adequate drainage in order to make it more productive. It is very important that tile be installed in practically all cases in order to prevent injury to crops from excessive moisture. The soil is well supplied with organic matter but it would respond to a small application of manure when it is newly drained. It is acid and in need of lime. Phosphorus fertilizers will certainly be needed in the future and they may be of value in some cases at the present time.

O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is a minor terrace type, covering 1.3 percent of the total area of the county. It occurs on the higher terraces along the Des Moines river and its larger tributaries from Des Moines north and along Indian

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creek. The largest areas of the type are found north of Des Moines partly within the city limits and in the vicinity of Johnston. The other areas of the type are practically all small and relatively unimportant.

The surface soil of this type is a dark brown to dark grayish-brown fine sandy loam 12 to 15 inches in depth. The subsoil is a dark brown to brown fine sandy loam, grading at about 27 inches to a lighter colored sand, and below this there is a layer of gravel and sand. In a few small areas along the upper course of the Des Moines river, along Beaver creek west of Camp Dodge and on Big creek, Four Mile creek and Indian creek, the lower part of the three foot section is a mixture of gravel and coarse sand.

In topography the soil is usually gently undulating to sloping or level. The terraces of the type are practically all above overflow. The soil is excessively drained and apt to be drouthy.

Probably 70 percent of the type is under cultivation, the chief crops being corn, wheat and oats. Some of the smaller areas are used for pasture. On the areas near Avon Station close to Johnston and north of Des Moines, truck growing is an important industry and watermelons, cantaloupes, sweet potatoes, cucumbers, tomatoes and cabbage are grown successfully. Early sweet corn does well also.

This soil is chiefly in need of organic matter in order to increase its ability to hold moisture during dry weather. Large applications of farm manure are very desirable. On the areas where trucking is practiced, particularly large applications of farm manure should be made. Leguminous green manure crops may often be used with profit on this type. It is acid and in need of lime. Applications of phosphorus fertilizers would probably be of value now for general farm crops and will certainly be needed in the near future. Where truck crops are grown, the application of brands of commercial fertilizers prepared for special crops would probably prove profitable.

BREMER SILT LOAM (88)

The Bremer silt loam is a minor terrace type, covering 1.2 percent of the total area of the county. It occurs along the Des Moines river, the Raccoon river and along Camp and Mud creeks. The largest areas are found directly north of Des Moines and south of Hastie along the Des Moines river, south of Des Moines and south of and west of Valley Junction along the Raccoon river. The areas along Mud creek and Camp creek are very small and relatively unimportant.

The surface soil of the Bremer silt loam is a dark brown to nearly black silt loam extending to a depth of about 14 inches. The subsoil is a dark brown silty clay loam grading gradually into a dark brownish-gray or grayish-brown silty clay loam. Along Camp and Mud creeks the soil has a brownish-gray or mottled dark brown and gray silty layer six to eight inches thick in the upper subsoil. In many of the smaller areas the color of the soil changes very little thruout the three foot section.

In topography this soil is level or slopes gently toward the streams. It is found on terraces 5 to 15 feet above the present stream channels. The type is fairly well drained and tiling is not generally needed.

Practically all of the Bremer silt loam is under cultivation, corn, wheat, oats and hay being the principal crops grown. Some sweet corn is produced in the

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vicinity of Des Moines. Yields of these crops are much the same as on the Bremer silty clay loam.

This is a rather productive soil and crop yields are generally fairly satisfactory. Small applications of farm manure would be of value but it is not advisable to apply this material immediately preceding the oats crop of the rotation owing to the danger of causing it to lodge. The type is acid and in need of lime. It will probably respond to applications of phosphorus fertilizers at the present time and in any case these materials will be needed in the near future. In some areas tiling may be of value if drainage conditions are not entirely satisfactory.

BREMER LOAM (12)

The Bremer loam is a minor type in the county, covering 0.9 percent of the total area. It occurs in small areas along the Des Moines river, Skunk river and Beaver and Walnut creeks. The largest areas are along the Des Moines river, north of Lovington and south of Des Moines.

The surface soil of this type is a dark brown friable loam extending to a depth of about 15 inches. This is underlaid by a very dark brown silty clay loam which below 24 inches passes into a dark brownish-gray or grayish-brown silty clay loam. In the more level areas the lower subsoil is quite compact. In the areas near the mouth of the North river there is considerably gritty material in the lower subsoil. A few areas lying along Beaver creek are highly calcareous and are really Fargo soils but they are too small to be shown separately on the map. In topography this soil is level to gently sloping. It occurs on terraces two to five feet above the overflowed bottomland. Most of the soil is above overflow except during periods of very high water. Most of the Bremer loam is under cultivation and the crops grown are the same as on the Bremer silty clay loam. The yields secured are very much the same as on the silty clay loam. This type is well drained and not in need of tiling. Small applications of farm manure would be of value. It is acid and in need of lime and applications of phosphorus fertilizers would probably prove of value in most instances.

BUCKNER FINE SANDY LOAM (45)

This is a minor terrace type in the county covering 0.7 percent of the total area. It occurs in small areas along the Skunk river, Beaver creek and the Des Moines river. The largest area is along Beaver creek north and west of Camp Dodge and there is also a rather considerable area in the northeastern part of the county along the Skunk river.

The surface soil of this type is a dark brown fine sandy loam extending to a depth of 12 to 18 inches. The subsoil is a dark brown to yellowish-brown fine sandy loam, which is quite loose and incoherent in the lower part of the three-foot section.

The topography of the soil is level to gently undulating. The soil is well drained but the drainage is rarely excessive. It occurs on high terraces, some of which are five to ten feet above the first bottoms, while others lie 25 feet above overflow land.

Probably 85 percent of the type is under cultivation, corn, oats and wheat being the principal crops grown. Watermelons, cantaloupes, sweet potatoes, cucumbers and tomatoes are grown to some extent on the type and give very

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satisfactory yields. A small portion of the type is used for pasture, being kept in native grasses or bluegrass.

This soil is particularly in need of organic matter and should receive liberal applications of farm manure in order to make it more productive. Leguminous green manure crops might be used to advantage. It is acid and in need of lime and phosphorus fertilizers will certainly be necessary in the near future.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is a minor type in the county, covering 0.7 percent of the total area. It occurs mainly in the southern part of the county along the Des Moines river, the Raccoon river and their tributaries. A few areas are found in the northern part of the county, one west of Johnston, one west and one south of Polk and a fourth three miles northwest of Santiago.

The surface soil of this type is a dark brown to nearly black smooth silt loam about 14 inches in depth. The subsoil is a yellowish-brown to brownish-yellow rather compact heavy silt loam to light silty clay loam. In a few of the smaller areas adjoining the Clinton silt loam in the southeastern part of the county, there is a shallow layer of dark gray silt loam on the surface. In the more level portions of the type southwest of Runnells the soil is heavier than typical and almost a silty clay loam.

In topography the type is flat to gently sloping. Drainage is good. The type occurs 10 to 40 feet above the stream channels and hence it is not subject to overflow. Practically all of the Waukesha silt loam is under cultivation, the principal crops grown being corn, oats, and wheat. Yields are very much the same as on the Waukesha loam and the treatment needed for the soil is very similar. Applications of farm manure would be very desirable. The soil is acid and in need of lime and phosphorus fertilizers would probably prove of value.

O'NEILL LOAM (108)

The O'Neill loam is a minor type in the county, covering 0.6 percent of the total area. It occurs in small disconnected areas along the Des Moines river, above the mouth of the North river, along the larger creeks in the western part of the county and along Indian creek in the northeastern part of the county. The areas are all small and none include over 200 acres.

The surface soil is a dark brown to dark grayish-brown loam 10 inches in depth. The subsoil to a depth of 24 inches is a brown loam to light silty clay loam which gradually becomes sandier at lower depths and is underlaid by a layer of gravel, coarse sand and small boulders. In the flatter areas the surface soil may be quite silty while in the more undulating areas it may become lighter textured. Frequently considerable coarse sand and gravel are found in the surface and thruout the soil section. Occasionally the supply of organic matter is so low that the surface soil is brown in color.

The topography of this soil is nearly level to gently undulating. Drainage is good to excessive and the soil is apt to be drouthy. It lies on high terraces 10 to 40 feet above the bottomlands.

Practically all of the larger areas of the type are under cultivation, the smaller ones being used for pasture. The crops grown are the same as on the Waukesha loam and the yields secured are very similar, except in dry years, when the yields are considerably reduced.

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This type is particularly in need of organic matter to make it more productive and permit of the better retention of moisture. Liberal applications of farm manure are very desirable and leguminous green manure crops may be used in some cases to advantage. The soil is acid and in need of lime. Applications of phosphorus fertilizers may prove profitable at the present time. They will certainly be needed in the future.

BREMER CLAY (44)

The Bremer clay is a minor type in the county, covering 0.3 percent of the total area. It occurs in many small areas along the various streams of the county and one large area south of Saylorville. Areas are found along Walnut creek, the Des Moines river and the Skunk river.

The surface soil of this type is a nearly black crumbly clay extending to a depth of about 18 inches. The subsoil is a very dark brown compact clay grading into a dark brownish-gray clay. In a few of the smaller areas the subsoil may have a pale yellow cast. In general, the entire soil section is dark in color and there is no distinct line of division between the soil and subsoil.

In topography the soil is level and drainage is poor. The installation of tile and the use of ditches will be necessary in order to make this soil more productive. It lies above ordinary floods but may overflow infrequently. Most of the small areas of this type are under cultivation, the same crops being grown as on the Bremer silty clay loam. The soil is apt to clod if plowed when too wet and will bake and crack upon drying. It is a late soil unless very well drained. Part of the larger areas is kept in native grasses and used for hay and pasture, yields of hay amounting to 1½ tons per acre annually.

The soil is particularly in need of drainage in order to make it satisfactorily productive. When this is accomplished it may be desirable to make a small application of farm manure in order to encourage the production of available plant food. It is generally acid and in need of lime and applications of phosphorus will be needed in the future.

O'NEILL FINE SAND (146)

The O'Neill fine sand is a very minor type in the county, covering 0.1 percent of the total area. It occurs in very small areas along the Skunk river in the form of low mounds rising in the areas of first bottom. Four other small areas are mapped with this soil because of their small extent. One is north of Polk, one north of Andrews, one south of Berwick and the other south of Peoria City. These areas are gravel pit residues and consist of a mixture of gravel, coarse sand and some clay. They are of no agricultural value.

The O'Neill fine sand has a grayish-brown to brown surface color and changes gradually into a yellowish-brown at lower depths. When it contains considerable organic matter, the surface may be dark grayish-brown in color.

In topography the soil is flat, the areas rising from 5 to 15 feet above the surrounding bottomland. Drainage is adequate to excessive. The soil is inclined to blow if not kept in cover crops.

Most of the O'Neill fine sand is used for pasture, supporting only a sparse growth of native prairie grasses. The remainder is cultivated with the adjacent soils or is occupied by farmsteads. Corn yields are generally unsatisfactory and small grains do not produce well. Some vegetables are grown for home use.

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This type is particularly in need of organic matter and should receive liberal applications of farm manure and, if this material is not available, leguminous green manure crops should be employed. The soil is acid and in need of lime. Phosphorus is low and phosphorus fertilizers would prove of value. In areas where truck crops are grown commercial fertilizers might be used with profit. With these treatments the soil may be made to produce as satisfactory general crops as the surrounding areas.

CHARITON SILT LOAM (105)

The Chariton silt loam is a very minor type in the county, covering only 0.1 percent of the total area. It occurs in several small areas in the county, three of them south of Camp Dodge and three southeast of Avon Station.

The surface soil is a dark gray to dark grayish-brown smooth silt loam extending to a depth of about 9 inches. From this point up to 20 inches the subsoil is a gray to light gray ashy silt loam. The lower subsoil is a drab colored impervious clay slightly mottled with brown. The lower subsoil is mottled with numerous reddish-brown iron stains. In one of the largest areas the subsoil shows some reddish-yellow mottlings in the lower depths. In the smaller areas the surface soil varies from a loam to a heavy fine sandy loam.

This soil occurs above overflow but water stands on it for long periods after heavy rains, owing to the impervious character of the subsoil. Drainage is very poor and tiling is necessary if the soil is to be utilized for cultivated crops.

Part of the type is in grass and used for pasture, the chief grasses being bluegrass and red top. On the cultivated areas corn, oats and wheat are grown. Fair yields of these crops are secured in normal seasons if the drainage is adequate. This is the first treatment needed for the soil. It would then respond to applications of farm manure. Lime should be used if needed and applications of phosphorus fertilizers would probably prove of value.

SWAMP AND BOTTOMLAND SOILS

There are 13 swamp and bottomland soils in the county and together they cover 14.0 percent of the total area. They are classified in the Wabash, Sarpy and Lamoure series.

WABASH CLAY (72)

The Wabash clay is the most extensive bottomland type, covering 4.1 percent of the total area of the county. It is developed primarily along the Skunk river, about 90 percent of it occurring in the bottoms along this stream. Other areas are mapped along the Des Moines river near Youngstown, south of Lovington and in the vicinity of Adelphi and Levey. There are also small areas along Indian creek and the Raccoon river. Along the Skunk river practically the entire bottoms are occupied by this type, while in the other areas the soil occurs in narrow strips and is associated with other bottomland types.

The surface soil of the Wabash clay is a very dark brown to nearly black clay. There is a very gradual change to the subsoil which is somewhat lighter in color and more plastic. It is usually a dark brownish-gray but may be drab colored in the smaller areas. It contains numerous iron stains. Small amounts of sand occasionally occur thruout the soil and near the stream

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channels a layer of sand two to three inches deep may cover the surface. In some of the narrower areas along the Des Moines river the soil may be lighter in color than the typical and occasionally there is a layer of sand in the lower part of the three foot section.

In topography the Wabash clay is flat. It is subject to overflow nearly every year except for the area south of Youngstown which is seldom flooded. The drainage of the type in general is poor. Water often stands on the surface after heavy rains and in the lower parts of the type the soil is somewhat marshy.

Less than 40 percent of the Wabash clay has been brought under cultivation, chiefly because of the unsatisfactory drainage of the type and because of the danger of overflow. In the cultivated areas corn is grown most extensively and wheat and oats are of secondary importance. Under favorable seasonal conditions corn produces from 40 to 70 bushels per acre and wheat 20 to 30 bushels per acre. Sweet corn is grown to some extent in the area along the Skunk river and the product sold to the canning factories. The yield of this crop amounts to 3 to 5 tons of ears per acre. On the stream banks there is some tree growth, consisting mainly of oak and elm. The greater part of the uncultivated land supports a luxuriant growth of slough grasses and is used for the production of hay and for pasture land. Slough grass produces from one to two tons of hay per acre and about 30 percent of the slough grass is cut for hay. The hay produced from the coarser leaved varieties is sold for packing purposes while that from the finer varieties is used for feed.

The chief need of the Wabash clay, if it is to be cultivated, is for adequate drainage. It should also be protected from overflow if crops are to be grown satisfactorily each year. It must be cultivated very carefully as it will clod and pack if plowed when too wet and it must be handled when the moisture content is just right if the physical condition is to be satisfactory thruout the season. It is very sticky when wet and cracks upon drying. The soil is apt to be in need of lime, especially after it has been drained and cultivated. A small application of farm manure would be of some value when the type is newly drained, but it is ordinarily very well supplied with organic matter. The phosphorus content will become deficient in the near future.

WABASH LOAM (49)

The Wabash loam is the second largest bottomland type in the county, covering 2.3 percent of the total area. It occurs chiefly along the various creeks of the county. Thus it is the main type in the bottoms along Four Mile creek, Walnut creek, Beaver creek and Big creek. Other areas are found along White Hall creek, Little creek, the upper parts of Mud creek and Camp creek. There are areas of the type also along the Des Moines river. It is found in long narrow areas ranging in width from a few hundred feet to a quarter of a mile and may occupy all or nearly all of the creek bottoms.

The surface soil of the Wabash loam is a dark brown to nearly black mellow loam 18 inches in depth. The subsoil is a dark brown to dark brownish-gray silty clay loam. In many places there is very little variation in the soil thruout the three foot section, but in general the subsoil is more compact than the surface. The surface soil is somewhat variable in texture, being heavier in the

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lower lying parts of the type back from the stream channels and sandier near the banks where it is most frequently overflowed. In some of the very narrow stream bottoms, the surface soil may vary from a fine sandy loam to a heavy loam.

In topography the Wabash loam is flat, but drainage is fair, owing to the old channels and sloughs which permit of the removal of excess moisture. Most of the type is subject to overflow, but the areas along the Des Moines river occupy somewhat higher positions than those along the creeks and they are subject to less frequent overflow.

Less than 20 percent of the Wabash loam is under cultivation, most of the type being used for pasture or for the production of hay. The small areas along the Des Moines river and some areas along Four Mile, Walnut and Big creeks are cultivated, corn, oats and wheat being the principal crops grown. Corn yields 40 to 45 bushels per acre, wheat 20 to 25 and oats 35 to 45 when the type is well drained, and in favorable seasons. Wild grasses grown on the uncultivated portion yield from 1 to 1½ tons of hay per acre. There are belts of timber on the type along the stream channels and this timber consists mainly of oak, elm, locust, hickory, black walnut and cottonwood.

Like the Wabash clay this soil is primarily in need of protection from overflow if satisfactory crops are to be grown each year. It is not so definitely in need of drainage as is the Wabash clay but in some instances drainage is necessary on the type. A small application of farm manure would be of value when the soil is newly drained and brought under cultivation. Phosphorus will eventually be needed but the type is fairly well supplied at present. It will undoubtedly become acid and in need of lime after it is brought under cultivation and well drained. The particular sample tested and reported in the analyses earlier in this report showed a basic reaction but this would not be true for the type as a whole.

SARPY LOAM (91)

The Sarpy loam is the third largest bottomland type, covering an area of 1.7 percent of the county. It occurs along the Des Moines and Raccoon rivers in relatively narrow strips varying in width from a few rods to ⅜ of a mile. The largest area is along the Raccoon river extending from the city of Des Moines beyond Valley Junction. There are many small areas of the type along the Des Moines river, particularly in the southern part of the county.

The surface soil of the Sarpy loam is a grayish-brown to brownish-gray friable loam extending to a depth of about 15 inches. The subsoil is a grayish-brown heavy loam to light silty clay loam which grades at 30 inches into a grayish-brown or a light grayish-brown very fine sandy loam to loamy sand or sand. The surface soil frequently contains much very fine sand and in the higher lying areas fine sand may occur thruout the soil section with the coarser textured subsoil nearer the surface. In the lower lying areas the surface soil of the type may be dark grayish-brown in color and quite silty in texture. In these areas the lower subsoil is usually a very fine sandy loam or light loam. There are some areas where the texture changes very little thruout the three foot section.

In topography the Sarpy loam is flat to very gently undulating. The drainage of the type, however, is good to excessive. On the higher areas where the

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Fig. 9. A view over the river, showing Sarpy soils in the bottoms.

coarse subsoil layer is nearer the surface, crops may suffer from drouth. In general, however, the type is not excessively drained but adequately so. It is all subject to overflow.

About 75 percent of the type is under cultivation, the remainder being occupied by towns or in pasture. In the latter areas there is some timber, consisting mainly of oak, ash, elm, walnut, willow and haw and there is a good growth of native grasses. On the cultivated areas corn is the most important crop, followed by wheat and oats. When protected from overflow corn yields 40 to 50 bushels per acre, oats 35 to 45 and wheat 20 to 25 bushels per acre. Clover and timothy yield from 1¼ to 1¾ tons of hay. Truck crops are grown to some extent on the type, chiefly near Levey. These consist chiefly of sweet corn, tomatoes, cabbage and beets, and the product is sold in the Des Moines markets.

This type is chiefly in need of protection from overflow if cultivated crops are to be grown successfully. It is basic in reaction and contains sufficient lime so that this material will not be needed for many years. It would be benefited by applications of farm manure and in the case of truck crops liberal applications of this material should be made. Phosphorus fertilizers will be needed in the near future and might be of value at the present time.

LAMOURE SILTY CLAY LOAM (111)

The Lamoure silty clay loam is a minor type in the county, covering 1.4 percent of the total area. It occurs along the creeks and smaller drainageways in the northern part of the county, being found in narrow strips along the smaller streams, in larger areas lying back from the stream channels and the larger creek bottoms and also in old lake beds or sloughs recently drained.

The surface soil of the Lamoure silty clay loam is a very dark brown to nearly black silty clay loam, extending to a depth of about 20 inches. The subsoil is a dark drab clay becoming somewhat lighter in color at the lower depths. In the smaller areas the lower subsoil appears somewhat yellowish and contains

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some coarse sand. Brown to reddish-brown iron stains frequently occur in the lower subsoil. Both soil and subsoil are highly calcareous. Where the type adjoins higher lying sandy soils there may be a surface covering which is distinctly loamy while near the center of the larger areas, the surface soil may be very heavy in texture.

This soil is level in topography and drainage is naturally poor. Water may stand on the surface for long periods after heavy rains. The type is generally subject to annual overflow.

About half of the area of this type is in native slough grasses and is utilized for pasture. The remainder of the type which has been drained with open ditches and tile, is used for the production of corn and on well drained land yields of 40 to 50 bushels per acre of this crop are secured. Small acreages are used for small grains but these are inclined to grow too rank in wet seasons.

This type is particularly in need of drainage and protection from overflow if it is to be cultivated. It must also be handled with care and not plowed or cultivated when too wet, as it is inclined to form clods. It also bakes and cracks in dry seasons. It is high in organic matter content and not particularly in need of applications of manure. However, small applications of fresh manure might be of value when the land is newly drained. Eventually it will need phosphorus. It is high in lime and should not be in need of this material for many years to come.

SARPY SILTY CLAY LOAM (144)

This is a minor type in the county, covering 1.3 percent of the total area. It occurs in the first bottoms along the Des Moines and Raccoon rivers. It is usually found along the older channels and sloughs, some distance back from the streams. The most extensive area of the type is found along the Des Moines river within the city limits.

The surface soil is a grayish-brown to dark grayish-brown silty clay loam extending to a depth of about 15 inches. This is underlaid by a dark brownish-gray silty clay loam grading at about 30 inches into a brownish-gray very fine sandy loam. In the lower lying areas there is more organic matter in the soil and it is a dark grayish-brown in color. Small areas of the silty clay or clay are included with this type, as they are too small to separate out. The texture of the lower subsoil is extremely variable and may range even in a single area from a very fine sand to a light silty clay loam. The entire three foot section of the soil is calcareous.

In topography the Sarpy silty clay loam is flat to undulating. Drainage on the lower areas is poor. Most of the type is subject to frequent overflow altho in the higher lying areas it is flooded only frequently.

Probably 60 percent of the type is under cultivation, the crops grown being corn, oats and wheat. Some sorghum is grown for sirup and for forage. Sweet corn is an important truck crop. On the lower lying areas the land is used for pasture and most of it is in grass and timber.

This soil is chiefly in need of protection from overflow if satisfactory yields of cultivated crops are to be secured. In some areas it may be in need of drainage but in general the drainage is fairly satisfactory. It is not in need of lime

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but would respond to applications of farm manure and phosphorus fertilizers will be needed in the future.

SARPY VERY FINE SANDY LOAM (28)

This is a minor type in the county, covering 0.9 percent of the total area. It occurs along the Des Moines and Raccoon rivers, being developed in strips varying in width from a few rods to half a mile along the channels of the streams.

The surface soil is a grayish-brown to brownish-gray very fine sandy loam extending to a depth of about 27 inches. Below this point the subsoil is a brownish-gray to gray very fine sand. On some of the minor elevations the surface 8 to 10 inches may be a very fine sand. Both soil and subsoil are highly calcareous.

In topography the type is billowy or gently undulating and the land is well drained. It lies 5 to 15 feet above the bed of the streams but is subject to more or less frequent overflow.

Much of the Sarpy very fine sandy loam supports a forest growth consisting of oak, elm, ash, walnut, cottonwood and willow. These areas are in grass and are used for pasture. Where the soil is cultivated the chief crop grown is corn; oats and wheat being grown to some extent also. Some sorghum is produced on this land and good yields of sweet potatoes, melons, cantaloupes, tomatoes, cabbage and beans are secured.

The soil is chiefly in need of protection from overflow if it is to be used for cultivated crops. Applications of farm manure would be of large value especially where truck crops are to be grown. It will be in need of phosphorus in the near future and phosphorus fertilizers might be of value now. For truck crops certain special brands of commercial fertilizers might be employed in certain cases.

WABASH SILTY CLAY LOAM (48)

This is a minor type in the county, covering 0.8 percent of the total area. It occurs chiefly along the Skunk river and Indian creek and along the Des Moines river south of Des Moines. It is found in numerous small areas along these streams, the larger areas occurring along the bottomlands of the Skunk river.

The surface soil of the Wabash silty clay loam is a very dark brown to nearly black silty clay loam extending to a depth of about 18 inches. The subsoil is a dark brown or dark brownish-gray rather compact clay loam or clay. In many places the lower subsoil is brownish-gray or drab. It contains numerous reddish-brown iron stains. Along the Skunk river the surface soil frequently contains considerable sand.

In topography this soil is flat and drainage is very poor. Water stands on the surface for some time after heavy rains. In general the type is subject to more or less frequent overflow, some of the areas along the Des Moines river being somewhat higher than the general level of the bottoms and being flooded only infrequently.

Most of the type is under cultivation, the same crops being grown as on the Wabash loam and the yields secured are very much the same. The uncultivated portion is in native grasses and is used for pasture and hay land.

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This type is particularly in need of adequate drainage and protection from overflow if cultivated crops are to be grown successfully. It is also important that it be properly handled and it should not be plowed when too wet as clods form readily and are difficult to break up by later cultivation. The soil is well supplied with organic matter but small applications of farm manure might be of value when it is newly drained. It is not generally basic in reaction and will be in need of lime when brought under cultivation. Phosphorus fertilizers will be needed in the future.

WABASH SILT LOAM (26)

This is a minor type in the county, covering 0.5 percent of the total area. It occurs entirely in the southern part of the county in the loessial area, being developed in long narrow strips from a few rods to one-seventh of a mile in width and covering nearly the whole of the first bottoms along the lower courses of Camp creek, Mud creek, Spring creek and Yeader creek. Small areas are also found along the Des Moines river and along the Raccoon river.

The surface soil of this type is a dark brown to nearly black loam extending to a depth of about 18 inches. The subsoil is a very dark brown silty clay loam becoming a brownish-gray in the lower part of the three-foot section. In areas adjacent to the Clinton silt loam the surface frequently has a shallow covering of lighter colored loessial material. In the small areas lying about two miles east of Avon Station the surface soil is shallower than typical and the subsoil is dark yellowish-brown.

The topography of the type in general is flat, altho the surface is broken in many places by old stream channels. The drainage of the soil in general is poor. Practically all of it is subject to annual overflow except the higher lying areas in the Des Moines river bottoms.

With the exception of the same small areas, the type is practically all in native grasses and forest and is used for pasture. The areas in the Des Moines river bottoms are generally cultivated and corn, oats and wheat are the principal crops grown. Yields are very much the same as on the Wabash loam.

The soil is fairly productive when protected from overflow and adequately drained. It will respond to applications of farm manure and lime, as it is generally acid. Phosphorus fertilizers will be needed in the future.

SARPY SILT LOAM (89)

The Sarpy silt loam is of minor importance in the county, covering only 0.3 percent of the total area. It occurs along the Des Moines river and the Raccoon river mainly south of Johnston, larger areas occurring east of Valley Junction and south of Commerce along the Raccoon river.

The surface soil of the Sarpy silt loam is a grayish-brown silt loam extending to a depth of about 15 inches. The subsoil to a depth of 30 inches is a brownish-gray to grayish-brown heavy very fine sandy loam. Below 30 inches it becomes a brownish-gray to gray very fine sand. In uncultivated areas the surface soil may have a dark grayish-brown color. Both soil and subsoil are calcareous.

In topography this type is flat to gently undulating to sloping and drainage is fairly good. The entire type is subject to overflow.

Most of the soil is under cultivation, crops grown and yields obtained being very much the same as on the Sarpy loam. It should be protected from over-

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flow if it is to be made satisfactorily productive when used for cultivated crops. It would respond profitably to liberal applications of farm manure or leguminous green manures. It may be somewhat acid in reaction in some cases. When this is true lime should be applied. Phosphorous fertilizers will be needed in the future.

RIVERWASH (53)

There is a very small area of riverwash in the county, amounting to 0.2 percent of the total area. It occurs in numerous small areas in bends or in small islands of the Des Moines and Raccoon rivers.

Riverwash consists of a mixture of fine, medium and coarse sand with some areas of gravel. This soil is not cultivated, owing to the frequency of overflow and the fact that the material is moved about considerably with each rise of the stream. Some of it supports a growth of willow or cottonwood and much is barren.

MUCK AND PEAT (21)

The total area of muck and peat in the county is small, amounting to 0.2 percent of the total area. The areas occur on the flatter uplands in the northern part of the county and along Beaver creek and north of Des Moines. They usually consist of areas from 5 to 15 acres in size, a few of the areas north of Crocker containing 30 to 40 acres.

The surface material of muck and peat consists of 6 to 20 inches of dark brown to black partly decomposed organic matter, derived from the remains of waterloving plants and grasses and with a small mixture of silt, clay or very fine sand washed in from the surrounding land. The surface material is loose and porous when dry but spongy when wet. Some of the material in the areas may be very finely divided and black in color but much of it is only partly decayed and still retains portions of the plant materials from which it has been formed. The underlying material is an impervious clay which is nearly black or dark drab, becoming lighter in color in the lower depths. Both the soil and subsoil are highly calcareous.

Muck and peat occur in small shallow depressions or old ponds and the topography is therefore flat to depressed and the natural drainage very poor. The first treatment needed to make such areas suitable for crop production is the installation of an adequate drainage system. When this is accomplished it is usually most desirable to seed down the areas to a mixture of timothy and alsike utilizing the crop either for hay or as pasture. The latter procedure is somewhat better as the trampling of the stock compacts the surface material and increases the rapidity of decomposition. Occasionally it may be desirable to grow such truck crops as potatoes, cabbage, tomatoes and onions, provided marketing facilities are available. The reclaimed areas near Herrold are utilized in this way and profitable yields of these truck crops are secured. Corn does not do well on newly reclaimed areas of muck and peat and should not be grown for several years after the areas have been drained. Small grain crops are not desirable, as they are apt to lodge. After the muck and peat have decayed for several years then corn and small grains may be grown successfully. Fall plowing is desirable on such areas and deep plowing is likewise desirable in order

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that the underlying clay may be opened up to some extent and aid in the making of a satisfactory soil condition. When these areas of muck and peat have been drained and decomposition has proceeded for a few years, large crop yields may be secured, as the natural fertility of the soils is high.

WABASH FINE SANDY LOAM (62)

The Wabash fine sandy loam is of very minor importance in the county, covering only 0.2 percent of the total area. Practically all of it is developed in small areas along the Skunk river.

The surface soil of the Wabash fine sandy loam is a dark brown fine sandy loam, becoming somewhat lighter in color and more compact in the subsoil. The lower subsoil may be a dark brownish-gray or brownish-gray in color. One or two areas along the Skunk river are a gray or dark gray very fine sand 8 to 12 inches in depth overlying typical Wabash clay.

In topography this type is generally sloping and the open nature of the soil material insures adequate drainage. The soil overflows frequently and unless protected cannot be used satisfactorily for cultivated crops. In favorable seasons corn will yield 30 to 50 bushels per acre, but ordinarily crop yields are not satisfactory.

The type is in need of protection from overflow, the application of farm manure, the application of lime, when acid, and the application of phosphorus fertilizers for the continued production of cultivated crops.

SARPY FINE SANDY LOAM (102)

This type is of very minor importance in the county, covering only 0.1 percent of the total area. It occurs in small isolated areas along the Des Moines and Raccoon rivers.

The surface soil of the type is a grayish-brown to brownish-gray fine sandy loam or loamy fine sand extending to a depth of about 14 inches. The subsoil is a grayish-brown, heavy fine sandy loam which at about 27 inches passes into a light grayish-brown loamy fine sand or fine sand. In some areas there is considerable coarse sand and fine gravel thruout the soil section.

In topography this type is flat but the drainage is good. The type is subject to overflow, lying 5 to 15 feet above the normal level of the streams.

Most of the Sarpy fine sandy loam is in cultivation and corn and sorghum are the most important crops. The type is usually included in fields with other soils. Yields are very much the same as on the Sarpy very fine sandy loam. On the uncultivated areas there is only a sparse growth of grass and in some portions practically no vegetation is found. This type is in need of protection from overflow and liberal additions of farm manure, and it will eventually need phosphorus.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

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AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their

*Bulletin 150, Iowa Agricultural Experiment Station.

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food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the

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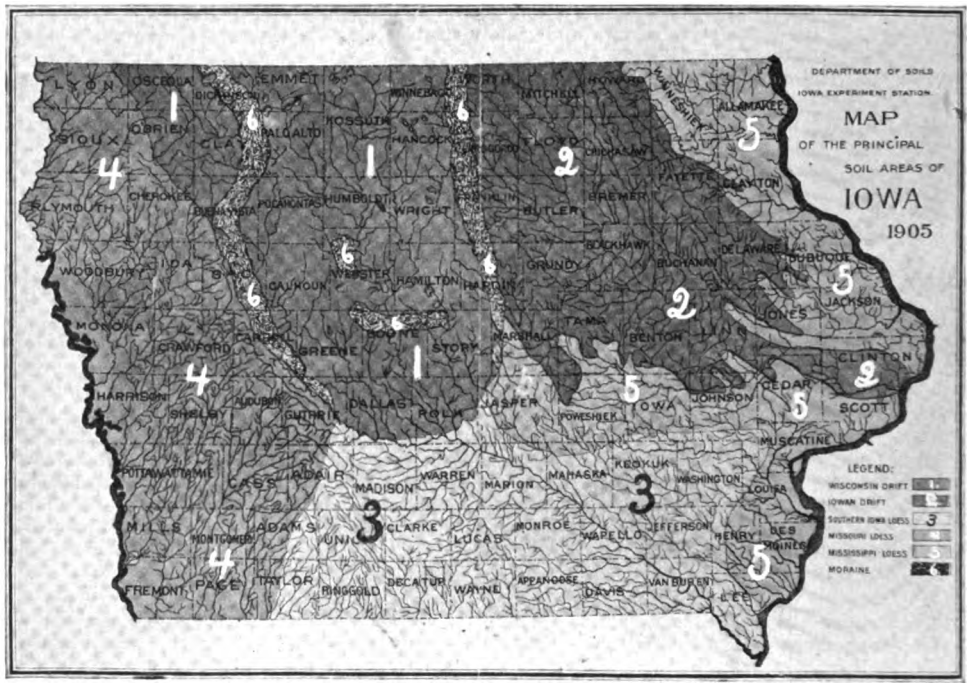

Fig. 10. Map showing the principal soil areas in Iowa

tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by

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differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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July, 1922 Soil Survey Report No. 25

SOIL SURVEY OF IOWA

Report No. 25—MARSHALL COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, E. I. Angell and H. J. Harper

A farm home on the Tama silt loam in Marshall county.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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MARSHALL COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, E. I. Angell and H. J. Harper

Marshall county is located in central Iowa, almost in the exact center of the state. It lies partly in the Iowan drift soil area and partly in the Southern Iowa loess soil area. Hence, both drift and loess soils are found in the county, the area covered by loess being very much larger, however, than that occupied by the drift soils.

The total area of Marshall county is 572 square miles or 366,080 acres. Of this area, 339,925 acres or 92.8 percent is in farm land. The total number of farms is 2,260 and the average size of the farms is 150 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land in the county:

Acreage in general farm crops	229,127
Acreage in pasture	90,530
Acreage in farm buildings, feedlots and public highways	18,800
Acreage in waste land	1,359
Acreage in crops not otherwise listed	500

The type of agriculture practiced in Marshall county at the present time is very largely livestock farming, altho general farming is perhaps the system most commonly followed. The livestock industry consists of the feeding of hogs and cattle, but the raising of hogs and other livestock is rapidly increasing. Grain farming, at least, in a modified form, is practiced to some extent and dairying is fast becoming an important industry.

The income of the county is derived in large part from the livestock industry, but much of the grain produced is still sold out of the county, and the sale of corn and oats adds materially to the income from the farms. On farms operated by the owners, very little of the grain produced is sold, practically all of it being utilized for feeding, while on tenant farms less feeding is done and much of the corn and oats is sold.

The area in waste land in the county is rather considerable and some method of treatment should be adopted which would permit of the reclamation of these areas. General recommendations for the best treatment of such land cannot be given, inasmuch as the causes of infertility are so variable. In a later section of this report special treatments which are particularly desirable for individual soil conditions will be indicated. In special cases for more or less abnormal soil conditions, advice regarding treatment may be obtained upon request from the Soil Section of the Iowa Agricultural Experiment Station.

The general farm crops grown in Marshall county in the order of their importance are corn, oats, hay, potatoes, wheat, barley, alfalfa and rye. The average yields and value of these crops grown in the county are given in table I.

Corn is the most important crop, both in acreage and value. Slightly over one-third of the total area of the farm land of the county is being devoted to this crop and average yields of 49 bushels per acre were secured in 1920. The most extensively grown variety is White Dent, other varieties grown being Reid's

*See Soil Survey of Marshall county, Iowa, by A. H. Meyer of the United States Department of Agriculture and E. I. Angell of the Iowa Agricultural Experiment Station.

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TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN MARSHALL COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	115,000	33.8	49.0	5,635,000	$0.47	$2,648,450
Oats	74,500	21.8	40.0	2,980,000	0.36	1,072,800
Winter wheat	630	0.1	23.0	14,490	1.41	20,430
Spring wheat	2,120	0.6	18.0	38,200	1.35	51,570
Barley	800	0.2	33.0	26,400	0.63	16,632
Rye	90	0.02	20.0	1,800	1.17	2,106
Hay (tame)	34,860	10.2	1.3	45,320	16.24	735,996
Hay (wild)	210	0.05	1.3	273	12.69	3,464
Alfalfa	70	0.02	3.0	210	19.23	4,038
Potatoes	847	0.2	121.0	102,487	1.22	125,034
Pasture	90,530	25.6	....	.....	....	.....

Yellow Dent, Pride of the North, Whipple Yellow Dent, Iowa Silvermine, White Cap Dent and Boone County White. About two-thirds of the corn crop is used for feed on the farms, for hogs and other livestock. On tenant farms, the major portion is sold. On most livestock farms, from 10 to 15 acres of corn is utilized for ensilage. In 1920 there were about 437 silos in the county.

The second crop in acreage and in value in the county is oats. It is grown on 21.8 percent of the farm land and average yields of 40 bushels per acre are secured. The value of the crop is less than half the value of the corn crop. The most popular varieties are the early maturing Iowa 103, Iowa 105, Kherson and Early Champion. The Green Russian is the most widely grown variety, but does not yield as well as the early maturing varieties. Early Amber and Silvermine are also grown to some extent. The greater part of the oats grown in the county is fed to the livestock, the remainder being sold to outside markets.

The third crop in value in the county is hay, clover and timothy constituting the leading hay crop. In 1920, over 10 percent of the total farm land of the county was occupied by tame hay. Only a relatively small acreage is devoted to wild hay. Average yields of clover and timothy amount to 1.3 tons per acre. Besides clover and timothy mixed, timothy is grown alone for hay and on a larger acreage, clover is grown alone. Small areas are devoted to millet and to certain tame grasses. Some red clover seed and timothy seed are produced. Clover yields two to four bushels of seed per acre on the average, and timothy, four to eight bushels. Practically all of the hay is fed to work stock and cattle, only a small amount being sold.

Potatoes are grown on a considerable area in the county and are the fourth crop in value. Average yields of 121 bushels per acre are secured. The main varieties grown are Rural New Yorker, Early Ohio, and some Early Rose. The production of potatoes is quite inadequate to meet the demands of the county and many are shipped in.

The acreage in wheat is rather small, and the amount of this crop produced is insufficient to meet the local demand. Spring varieties are grown more extensively than the winter varieties. The total value of the spring and winter wheat is considerably less than that of corn and oats. Average yields of 23 bushels

*Iowa Yearbook of Agriculture, 1920.

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per acre are secured for the winter varieties, chiefly Turkey, and 18 bushels for the spring varieties, Marquis and Java. Barley and rye are grown to a small extent, and alfalfa is also grown on a small area. The value of these crops is not large in the aggregate, but may be considerable on individual farms.

Alfalfa is being produced more extensively and yields of three tons per acre are secured on the average. An increased acreage in this crop will result from a better knowledge of the soil conditions which are necessary for its satisfactory growth. The addition of lime is particularly necessary for alfalfa growing and the conditions must be such that the soil is well drained and aerated.

Other crops of minor importance grown in the county are buckwheat, rape, flaxseed, sweet potatoes, sweet corn, sorghum, Sudan grass, soybeans, popcorn, pumpkins, tomatoes and cabbage. Rather considerable areas are devoted to sweet corn production, especially near Marshalltown and Gilman, the product being utilized by the canning factories in those cities. Stowell's Evergreen is the variety most commonly used, altho Country Gentleman and Early Evergreen are also grown. Sorghum is grown in small patches by many farmers and utilized for sirup and for feed. Some Sudan grass is produced and the seed finds a ready market. This crop makes excellent pasture. Soybeans give promise of becoming an important crop in the future.

Pumpkins, tomatoes and cabbage are produced in quantities near Marshalltown and supplied to the canning factory. The sale of these crops provides considerable income on some farms. Watermelons and cantaloupes also are grown to some extent, and vegetables other than potatoes are produced on rather large areas, particularly near Marshalltown. The trucking industry, however, is not very largely developed in the county.

There are no strictly commercial orchards in the county, but most farmers have a small number of fruit trees, chiefly apples, plums, cherries and pears. These fruits are utilized for home consumption to a large extent, altho in some years there is a rather considerable sale out of the county. Small fruits such as strawberries, blackberries and raspberries are also grown to some extent.

THE LIVESTOCK INDUSTRIES OF THE COUNTY

The livestock industries of the county include dairying and the raising and feeding of cattle and swine. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the numbers of livestock in the county:

Horses (all ages)	14,155
Mules (all ages)	659
Swine (on farms July 1, 1920)	100,868
Swine (on farms Jan. 1, 1921)	76,314
Cattle (cows and heifers kept for milk Jan. 1, 1921)	11,151
Cattle (other cattle not kept for milk Jan. 1, 1921)	33,283
Cattle (all ages)	44,434
Sheep (all ages on farms Jan. 1, 1921)	12,780
Sheep (shipped in for feeding during 1920)	9,567
Sheep (pounds of wool clipped)	69,467
Poultry (total all varieties Jan. 1, 1921)	259,099
Poultry (number of dozen eggs received, 1920)	1,067,176

The dairy industry is receiving an increasingly large amount of attention in the county, and most of the products from dairy farms are supplied to the local creameries, to the local markets and to outside points. Practically all of

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the farmers keep dairy cows, chiefly Shorthorns or Holsteins, and in most cases, of course, the dairy products are utilized largely for home consumption. The value of the dairy products of the county has been estimated at over half a million dollars during the year 1920.

The feeding of beef cattle is practiced to a large extent in the county, the stock being sold in the Chicago and Omaha markets. The raising of beef cattle is also an important industry and there are a number of herds of Shorthorns in the county, and some Aberdeen Angus and Hereford herds.

The breeding of farm and draft horses and mules is receiving some attention, nearly every farmer raising one or two colts each year. The Percheron and Belgian are the favorite breeds.

The raising and feeding of sheep has increased to a considerable extent in the county during the past few years and the income from this industry is rather large. Most of the sheep are shipped to Chicago.

The raising of hogs is the most important livestock industry and the number of farmers specializing in it is increasing. Duroc Jersey, Poland China, Chester White, Hampshire and Berkshire are the leading breeds. Practically all farmers raise enough hogs to supply their own demands, and on the livestock farms the raising of hogs constitutes a major source of income, the hogs being marketed in Waterloo, Mason City and Cedar Rapids. According to estimate, in 1920 the value of the hogs on the farms of the county was over $2,000,000.

The raising of poultry is becoming of some importance, and the value of the poultry products is considerable. They are sold in large part to a local firm in Marshalltown and shipped to Chicago, New York and Boston.

The value of the land in Marshall county is rather variable, depending upon the location with reference to towns and to railroad facilities, the improvements on the farms and general soil conditions. The average price of farm land is about $250 per acre. The range in selling price varies from about $50 to $350. In some instances the land has sold at a considerably higher figure than this and it is generally recognized that much of the land in the county is extremely valuable for general farming purposes.

The yields of general farm crops in Marshall county are usually satisfactory, but in many instances proper methods of soil treatment would undoubtedly bring about more profitable yields. The particular treatments which are needed vary somewhat, depending upon the soil conditions or upon the characteristics of the individual soil type. Topography features are also frequently of significance.

In some instances drainage is not entirely satisfactory, and when this is true, the first treatment needed to insure satisfactory crop growth is the installation of tile. No other treatment will be of value if the soil is too wet and whatever the expense involved in putting in tile, the value of the greater crop growth secured will more than make up for the outlay.

The soils of the county are very largely acid and applications of lime are quite generally necessary for the best growth of farm crops, particularly legumes. Only in one instance is there any large occurrence of carbonates in the soil and in this case lime would not, of course, be necessary. In the other instances where a basic reaction has been found, the lime content is small and the surface

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soils will soon be in need of applications of this material. All the soils of the county should evidently be tested for lime requirement, especially before any attempt is made to grow legumes.

In some instances, the soils of the county are not very well supplied with organic matter and applications of farm manure and green manures should be made in order to put the soils in better condition for crop growth. In the case of several of the upland types, however, and also in some of the bottomland soils, the amount of organic carbon present seems to be considerable and it might be assumed that these soils would not respond to fertilization with farm manure. In all cases, however, the application of this material has led to increases in crop growth and it may safely be said that on all the soils of the county, farm manure should be applied in liberal amounts, and where it is not available, leguminous green manures should be used. On the light sandy types of soil, the use of these materials is particularly necessary and in many instances other fertilization would be of practically no use until the organic matter content of the soils is built up.

The nitrogen content of the soils is not strikingly low except in one instance, but care should be taken to keep up the supply of this constituent. This may be accomplished thru the use of leguminous green manure crops.

The phosphorus supply is not particularly high in any case, and in most of the soils it is rather low. Need of phosphorus fertilization on the soils of the county, if not acute at the present time, will soon become evident. Applications of phosphorus fertilizers to small areas are suggested at the present time in order to determine whether or not these materials will prove profitable. Acid phosphate and rock phosphate may both be used in such tests to learn which material will prove the most profitable.

Complete commercial fertilizers are not recommended at the present time for the soils of the county, but any who are interested in these materials may include tests of them along with the phosphorus tests.

Erosion is occurring to some extent in Marshall county and it is very desirable that precautions be taken to prevent the extensive washing away of the surface soil and to stop the formation of gullies.

THE GEOLOGY OF MARSHALL COUNTY

The early geological history of Marshall county is of practically no significance from the standpoint of present-day soil conditions. The original bed rock material in the county has been buried so deeply by the glacial deposits that there is no effect of this material upon the soil characteristics.

At least three times during the glacial age great glaciers invaded the county and each time, upon their retreat, left behind an enormous mass of glacial drift or till, which covered the entire surface of the land. The topographic features of the county which had been established prior to the coming of the glaciers were very largely obliterated at the first invasion. Later glacial action remodeled, to a large extent, the topographic features developing in the earlier drift deposits and covered them with deep layers of new drift. Hence there is found over the surface of the county layers of drift of varying depths, representing the glacial material laid down by the various ice sheets.

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The earliest drift deposit is known as the Kansan and it varies in different parts of the county from a few feet to a hundred feet in thickness. This drift material is underlaid in some places by layers of stratified sand and gravel containing many pebbles and small boulders. This layer may extend to a depth of thirty feet. The Kansan deposit is composed mainly of boulder clay, varying in color from a bright yellow to a deep reddish-brown, where exposed to oxidation, and to a blue when unoxidized. Pockets of sand and gravel occur and boulders are frequently found.

Following the retreat of the Kansan ice sheet, beds of gravel known as the Buchanan gravels accumulated, and remains of these gravel beds occur in some parts of the county.

At a later date a second glacier invaded the county, crossing the northeastern corner. The deposit left by this glacier is known as the Iowan drift and it usually extends to a depth of not more than 10 feet. It is light to bright yellow in color and is sandier than the Kansan drift. Boulders, usually of a larger size than those found in the Kansan till, are of frequent occurrence. The entire drift material shows its more recent origin and hence there is less evidence of weathering.

Still later, a third glacier crossed the western part of the county, depositing, upon its retreat, a layer of drift known as the Wisconsin. The upper part of this drift material is a dull yellow in color and apparently has been leached to a much less extent than the Iowan and Kansan drift material. In the lower parts it is a blue boulder clay, less impervious, however, than the Kansan. Boulders are very common in this drift material and consist mainly of granite. In most cases the material below a depth of four feet effervesces with hydrochloric acid, indicating the occurrence of carbonates. This is the only drift material which is exposed at the surface over any extensive areas in the county. The Carrington loam is derived from this Wisconsin till and this type is found mainly along the western edge of the county.

Following the glacial age there was a deposition of loess over practically all of the county with the exception of the western portion just noted. This layer of loess is extremely variable in depth, ranging from a few inches to 20 feet.

Along the streams and in the rougher portions of the county, the loess covering has been removed to a considerable extent and there are areas of soils of the Shelby and Lindley series which are derived practically entirely from the underlying drift material. The loess soils of the county are classed in the Tama, Muscatine, Knox and Clinton series.

In its unweathered condition, loess is an even-grained material, composed largely of silt. It ranges in color from a light grayish-brown to a yellowish-brown. Organic matter has accumulated quite generally in the surface soils and there has been a development of a darker soil. Under prairie conditions abundant plant growth, with the resultant vegetable residues, has led to the formation of almost black soils. The Muscatine and Tama soils, the leading loess types in the county, are quite generally dark brown to black in color. Where the loess has weathered under wooded conditions, erosion has been active and more leaching has occurred. Organic matter has not accumulated to such

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a large extent and the soils are lighter in color, varying from a gray to light brown. This is true of the Clinton and Knox series.

The variation in fertility in these loess soils is considerable, depending upon the topographic conditions, the drainage and the character of the plant growth. Thus, the Muscatine and Tama soils are much richer than the Clinton and Knox types. In all cases lime has been practically entirely removed from the surface soil and these types are all in need of lime.

In addition to the upland soils, which are either of loessial or drift origin, there are considerable areas of terrace or second bottom soils and of first bottoms. These are very largely made up of loessial material washed down from the uplands.

PHYSIOGRAPHY AND DRAINAGE

In topography Marshall county consists in general of three distinct divisions, which correspond rather closely with the areas covered by the Wisconsin, the Iowan and the Kansan drifts [illegible] Swamp and bottomland soils are those occurring in low, poorly-drained areas or along streams and are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Marshall county are shown in table II.

Over one-half of the total area of the county, 67.7 percent, is covered by loess soils, the area of uplands covered by this group including practically the entire central portion of the county. The drift soils cover 19.8 percent of the total area of the county and occur mainly along the western boundary. Terrace soils are of only minor occurrence, together covering 2.9 percent of the county, and swamp and bottomland soils are found covering 9.6 percent of the total area, the larger areas of these soils occurring along the Iowa river.

There are fifteen individual soil types in the county and these, together with the area of muck, make a total of sixteen separate soil areas. There are five drift soils, four loess types, three terrace soils and four areas of swamp and bottomland. These various soil types are distinguished by certain characteristics which are described in the appendix to this report, and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Tama silt loam is the largest individual soil type, covering over half the total area of the county. The Carrington loam is the largest drift soil and the second largest soil type, covering, however, but 10.2 percent of the total area. The Shelby loam is the third largest type and the second largest drift soil, covering 7.0 percent of the total area. The Wabash silt loam is the largest bottomland soil and the fourth type in the county, being only slightly smaller

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN MARSHALL COUNTY

Soil group	Acres	Percent of total area of county
Drift soils	72,576	19.8
Loess soils	247,872	67.7
Terrace soils	10,688	2.9
Swamp and bottomland soils	34,944	9.6
Total	366,080	100.0

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TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MARSHALL COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	37,440	10.2
79	Shelby loam	25,792	7.0
65	Lindley loam	3,584	1.0
4	Carrington fine sandy loam	3,136	0.9
85	Clyde silty clay loam	2,624	0.7
	LOESS SOILS		
120	Tama silt loam	217,600	59.4
30	Muscatine silt loam	17,792	4.9
80	Clinton silt loam	10,816	2.9
141	Knox loamy fine sand	1,664	0.5
	TERRACE SOILS		
75	Waukesha silt loam	5,184	1.4
38	Buckner loam	4,800	1.3
43	Bremer silty clay loam	704	0.2
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	25,536	7.0
49	Wabash loam	5,248	1.4
48	Wabash silty clay loam	4,096	1.1
21a	Muck	64	0.1

in extent than the Shelby loam. The Muscatine silt loam is the next type in area and the second loess soil, covering 4.9 percent of the county. The Clinton silt loam is much smaller in extent and covers 2.9 percent of the county. The remaining soil types are all very minor in area, many of them covering less than 1 percent of the county. The terrace soils are all minor in area, the largest of these occupying only 1.4 percent of the county.

The upland soils of Marshall county are quite generally undulating to rolling in topography. This is characteristic of the Tama and Clinton soils of the loess soil group and also of the Carrington and Shelby soils of the drift soil group.

The Clyde silty clay loam, a drift soil, and the Muscatine silt loam, a loess soil, are more level in topography and are characterized by less adequate drainage systems. In the terrace and swamp and bottomland soil groups, the soils of the Bremer and Wabash series are level in topography and, in general, poorly drained. The Waukesha soils and Buckner soils are better drained and gently undulating in topography.

In some parts of the county the topography is almost rough. This occurs where the soils are in the Lindley series and sometimes where the Shelby and Clinton soils are found. The Carrington fine sandy loam and the Knox loamy fine sand, both very minor in extent, have the gently rolling topography of the major upland soils of the county. As has been noted, the topographic condition of the county, together with the rather complete drainage system, permits adequate drainage of most of the soils.

THE FERTILITY IN MARSHALL COUNTY SOILS

Samples were taken for analyses from each of the soil areas in the county, except the area of muck. The more extensive types were sampled in triplicate, while only one sample was taken in the case of the minor types. All samplings

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were made with the greatest care that the samples should be representative of the particular soil types and that variations due to local conditions or previous treatment should be eliminated. The samples were drawn at three depths, 0"—6 2/3", 6 2/3"—20" and 20"—40", representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods, and the Veitch method was followed for the limestone requirement determinations. The figures given in the tables are the averages from the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is quite variable, ranging from 612 pounds per acre in the Knox loamy fine sand up to 2,027 in the case of the Clyde silty clay loam. There is no distinct relationship apparent between the phosphorus content of the soils within the four groups. The average of the bottomland soils is slightly higher than that of the other groups, which might be expected, inasmuch as the crop production on these types has been limited and there has been very much less removal of this constituent than takes place normally on cropped soils on the upland. The terrace types are slightly higher than the loess and drift soils, on the average, but the differences are in general too small to permit of definite conclusions. In fact, the variations within the various soil groups are larger than the variations between groups. Thus, there is a range from 976 pounds to 2,027 among the drift soils, and the loess types range from 612 to 1,430 pounds.

TABLE IV. PLANT FOOD IN MARSHALL COUNTY, IOWA, SOILS
Pounds per acre of 2,000,000 pounds of surface soil (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
1	Carrington loam	976	3,880	44,820	0	3,864
79	Shelby loam	1,097	3,068	31,780	0	2,318
65	Lindley loam	1,212	1,766	16,658	32,042	Basic
4	Carrington fine sandy loam	1,097	2,270	29,160	0	2,705
85	Clyde silty clay loam	2,027	5,884	77,698	1,402	Basic
	LOESS SOILS					
120	Tama silt loam	1,430	6,010	73,338	263	1,030
30	Muscatine silt loam	1,279	5,520	68,400	0	4,250
80	Clinton silt loam	1,225	3,418	41,020	0	773
141	Knox loamy fine sand	612	532	7,580	0	1,932
	TERRACE SOILS					
75	Waukesha silt loam	1,528	4,190	47,140	0	4,637
38	Buckner loam	1,097	3,320	42,800	0	3,478
43	Bremer silty clay loam	1,775	4,644	58,952	2,128	Basic
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,899	6,894	80,680	0	2,318
49	Wabash loam	1,003	3,404	40,206	2,854	Basic
48	Wabash silty clay loam	1,724	6,010	71,140	0	1,159

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When the individual soil types are considered, however, there seems to be some relation between the phosphorus content and the soil series and texture. Thus, the silty clay loams are generally considerably higher in phosphorus than the lighter textured types. This is probably due, in large part, at least, to the fact that soils of this texture are more level in topography and apt to be inadequately drained. Hence crop growth has been reduced and the removal of the original stock of phosphorus has been less rapid. Among the bottomland soils the Wabash silt loam is slightly higher than the silty clay loam, but the topographic and cropping conditions on these bottoms is such that the effect of the soil texture would naturally be less evident. Fine sandy loams and other light textured types would naturally be low in phosphorus, as well as in other plant food. The loams seem to be lower in phosphorus than the silt loams, even when they are of different series. This would not always hold true, however, and generally comparison should only be made within the series. In general, these analyses bear out the belief that the heavier textured soils are apt to be richer in plant food constituents than the lighter textured types.

It is evident from the figures given that the phosphorus supply of the soils of Marshall county is rather low in many cases and phosphorus fertilizers will undoubtedly be needed on these soils in the near future if satisfactory crop yields are to be secured. Even if these materials are not absolutely necessary at the present time, phosphorus must be taken into account in planning systems of permanent fertility. Of course, there is never any assurance from analyses that sufficient phophorus would be produced in an available form from any soils, but when the general soil conditions are satisfactory, it may generally be assumed that a fairly rapid production of the element in an available form will occur. When the total supply is as low as is the case in many of the soils of this county, however, it is safe to say that the supply of available phosphorus would probably be insufficient in many cases. It seems probable, therefore, that phosphorus fertilizers might be used with profit on some of these soils at the present time. Individual farmers are urged to test phosphorus fertilizers on small areas on their own farms and thus determine for their own conditions whether or not these materials are profitable. Small areas may be treated with a phosphorus fertilizer and if crop yields are increased profitably, then the same material may be applied to larger areas with assurance of profit.

The nitrogen content of the soils of the county is even more widely variable than the phosphorus supply, ranging from 532 pounds in the case of the Knox loamy fine sand, up to 6,894 pounds in the Wabash silt loam. In general the soils of the county do not seem to be strikingly deficient in nitrogen, with the exception of the Knox loamy fine sand mentioned above. The Lindley loam, while not so low as the Knox loamy fine sand, is not very well supplied with nitrogen and the Carrington fine sandy loam likewise is not particularly rich in this constituent. Most of the silt loams, loams and silty clay loams of the upland, however, are fairly well supplied.

There is no relation between the amount of nitrogen present in the soils of the various soil groups, altho the average of the bottomland soils is higher than that of the other groups, which might be expected for the same reasons which

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were suggested in the case of phosphorus. There is some evidence, however, of a relationship between the soil texture and the nitrogen. As in the case of phosphorus, the heavier textured types generally contain more nitrogen. The silty clay loams and silt loams are better supplied with this constituent than the loams, and the latter soils are much richer than the sandy types.

While it is evident from these analyses that, except for one or two minor types, the soils of the county are not extremely low in nitrogen, this element must not be neglected in planning systems of permanent soil fertility. The treatments practiced in the case of all the soils must include the addition of nitrogenous fertilizing materials if the supply of this element is not to become deficient. Farm manure returns to the soil considerable amounts of nitrogen that have been removed by crop growth, and it constitutes, therefore, a very important fertilizing material from the nitrogen standpoint. Crop residues likewise return a portion of the nitrogen taken from the soil. Both these materials aid in keeping up the supply of nitrogen, but by their use alone there is a constant decrease in nitrogen in the soil, owing to the fact that complete return cannot be made. Leguminous green manures are often used as supplements to or substitutes for farm manure and they increase the nitrogen supply in the soil by utilizing the free nitrogen of the atmosphere. This is only accomplished when the legumes are inoculated, and the actual amount of nitrogen added is extremely variable, depending upon many factors, such as thoroness of inoculation, character of the crop grown, and nitrogen content of the soil. For the clovers it is believed that the nitrogen content of the tops is equal to that taken from the air and hence the supply in the soil is increased by an amount which is determined by the size of the crop. Leguminous green manures constitute the cheapest and best source of nitrogen and the practice of green manuring is of value in building up soils low in nitrogen, and in keeping up the supply of this constituent.

The supply of nitrogen in soils may be increased, therefore, by the use of farm manures, crop residues and leguminous green manures, but these materials have an additional value in that they also keep up the supply of organic matter or organic carbon in soils. In fact, there is a distinct relation between the nitrogen and organic carbon in soils. The content of both these constituents is rather definitely indicated by the color of the soil. If it is black, the organic carbon and nitrogen content is high. If it is light, the supply of these constituents is low.

The soils of this county show a wide variation in organic carbon content and in the case of each type there is rather definite relation to the nitrogen supply and also to the color of the soil. Where the nitrogen is low, the organic carbon is likewise low. Where the nitrogen is high, there is a large amount of organic carbon present. Again, there is no relation between the supply of this constituent and the various soil groups. There is, however, a relation between the texture of the individual soils and the organic carbon content, just as in the case of nitrogen. The heavier textured soils are high in organic carbon, while the light textured types are low in this constituent. The heavier textured types are all dark in color, so that there is the same relationship between the organic carbon content and the color of the soil.

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The relation between the carbon and nitrogen present in soils gives rather definite evidence of the rate at which plant food is being made available. In practically all cases the relation between these constituents in the soils of Marshall county is satisfactory. In two or three instances, however, the relation is not the most desirable one. In these instances applications of farm manure would prove particularly valuable because of the fact that this material brings about a more rapid decomposition of organic matter and a greater production of available plant food. This does not mean that farm manure would not be of value on any of the soils in the county, but merely that its effects are more pronounced where there is stimulation in the available plant food production. In fact, the use of farm manure on the soils of the county is strongly to be urged, even where the organic matter content is rather high and the color is quite dark. This material will prove of considerable value in all cases, as is evidenced by the results of field tests and much farm experience, and it should be applied in as liberal amounts as possible. If there is not sufficient manure available to apply to all the soils on the farm, leguminous green manures should be used to make up the deficit. All crop residues should also be used on these soils in all cases. It should be clearly understood that if the soils are to be kept up in fertility and if they are to be made as highly productive as possible, the organic matter supply must be maintained carefully.

Several of the soils of the county show a small content of inorganic carbon, but only in one instance is the amount of this constituent very considerable. The Lindley loam shows a rather high content and the amount present in this case is sufficiently large so that it will be some time before acidity develops. Where inorganic carbon is present, even tho only in small amounts, there is no lime requirement shown by the tests, except in one instance where the inorganic carbon is hardly more than a trace and the acidity is very slight. Four of the soil types give a basic reaction and hence indicate that lime would not be necessary for application at the present time, but as the inorganic carbon content is low, the soils will soon become acid and will need lime. In the types where acidity has developed, the lime requirement of the particular samples is extremely variable.

There is no relation between the limestone requirement, as shown in the table, and the soil group, soil series or texture, and, indeed, the determinations which are constantly being made on many samples from all over the state indicate that there may be wide variations in acidity in different samples of the same soil type. The figures given in the table, therefore, should be considered merely indicative of the needs of the soil types and should not be taken as recommendations for field treatments of these soils. They do indicate, however, that many of the soils of the county should be tested for acidity and lime requirement, and even in those instances where the particular test reported showed the soils to be basic, tests will be necessary in the near future as, with one exception, the supply of inorganic carbon is not high. Lime disappears from soils rather rapidly when they are under cultivation and well drained, and it is constantly necessary to resupply to soils the lime which is removed by leaching and cropping. If the soils of this county are to produce the most profitable yields of all crops and particularly of legumes, they should

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be tested for acidity at regular intervals, at least once in every four-year rotation, and the lime shown to be necessary should be applied.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils appear in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

Unless there is a very large amount of plant food present in the lower soil layers, there is very little effect upon the fertility of the soil, and hence the analyses of the surface soils are usually sufficient to indicate the plant food supply of the soil and indirectly its crop-producing power. The lower soil layers in Marshall county do not seem to be very high in any of the plant food constituents determined and hence the fertility of the soils will be very little influenced by the varying subsoil conditions. It is hardly necessary, therefore, to consider these results in detail. The needs of the individual soils, as indicated by the results of the analyses of the surface soils are very largely borne out by the results in these lower soil layers. Phosphorus fertilizers will certainly be needed in the future. They might be of value in some cases at the present time. The supply of organic matter and nitrogen must be increased in some instances, and kept up in all cases, by the use of farm manure, crop residues and leguminous green manure.

In general, the soils which react basic at the surface show the same reaction in the lower layers, in one or two instances the amount of inorganic carbon present increasing in the subsoil. In two cases soils which were acid at the surface gave a basic reaction in the lower layers, but in neither instance was there any considerable amount of inorganic carbon present. Only in the Lindley loam, the same soil which showed a high content of inorganic carbon in the surface, is there any considerable supply of this constituent in the lower

TABLE V. PLANT FOOD IN MARSHALL COUNTY, IOWA, SOILS
Pounds per acre of 4,000,000 pounds of subsurface soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
1	Carrington loam	1,670	6,556	78,560	0	5,410
79	Shelby loam	1,898	3,504	39,360	0	3,864
65	Lindley loam	2,114	1,008	2,288	91,912	Basic
4	Carrington fine sandy loam	1,427	3,420	32,800	0	3,864
85	Clyde silty clay loam	2,195	2,352	39,368	592	Basic
	LOESS SOILS					
120	Tama silt loam	2,016	6,901	88,363	330	1,546
30	Muscatine silt loam	1,697	6,248	74,680	0	5,410
80	Clinton silt loam	2,222	2,296	22,880	0	1,546
141	Knox loamy fine sand	1,454	794	6,580	900	Basic
	TERRACE SOILS					
75	Waukesha silt loam	2,451	6,220	79,360	0	7,728
38	Buckner loam	2,263	5,688	68,160	0	1,546
43	Bremer silty clay loam	1,879	6,388	84,444	256	773
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,680	7,788	98,000	0	6,182
49	Wabash loam	2,451	5,996	74,292	5,628	Basic
48	Wabash silty clay loam	2,438	6,892	95,692	508	Basic

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TABLE VI. PLANT FOOD IN MARSHALL COUNTY, IOWA, SOILS
Pounds per acre of 6,000,000 pounds of subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
1	Carrington loam	2,343	4,542	49,980	0	5,796
79	Shelby loam	2,606	2,268	25,680	0	6,954
65	Lindley loam	3,374	924	1,944	136,980	Basic
4	Carrington fine sandy loam	1,777	3,318	40,860	0	3,577
85	Clyde silty clay loam	3,232	2,520	33,078	1,002	Basic
	LOESS SOILS					
120	Tama silt loam	2,643	6,446	73,127	793	3,091
30	Muscatine silt loam	1,737	4,962	62,940	0	3,577
80	Clinton silt loam	4,222	2,520	29,040	0	3,577
141	Knox loamy fine sand	2,081	714	7,513	1,307	Basic
	TERRACE SOILS					
75	Waukesha silt loam	3,636	4,752	49,620	0	4,638
38	Buckner loam	2,424	5,382	53,700	0	3,577
43	Bremer silty clay loam	2,879	4,161	51,718	1,092	Basic
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,878	4,668	82,800	0	3,577
49	Wabash loam	4,283	12,780	158,354	5,206	Basic
48	Wabash silty clay loam	3,051	4,374	71,709	711	Basic

soil layers. Hence, the conclusions drawn from the surface soil would apply equally to the subsoil. In fact, the amount of lime present in the subsoil is of very little significance in reducing the acidity of the soil. Lime generally moves downward in the soil and if the surface soil is acid, lime must be applied regardless of the content of the subsoil. In general, it may be concluded that the soils of Marshall county should be tested at regular intervals for acidity and, when acid, lime should be applied as needed, without considering the subsoil conditions.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Marshall county in order to secure indications of the fertilizer needs of the soils and to learn the value of the application of certain common fertilizing materials. These experiments were carried out on the Tama silt loam and the Carrington loam, two of the more important types in the county. The results of experiments on the Tama silt loam from Black Hawk county and the Carrington loam from Bremer county are also included, inasmuch as they very largely confirm the experiments on the same types in Marshall county. The plan of all these experiments was much the same, with the exception of the test on the Bremer county soil.

The treatments used were manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The size of the applications was the same as used in the field tests and hence the results of these greenhouse experiments may be considered definitely indicative of the results which may be secured in the field. Manure was applied at the rate of 8 tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil as indicated by the Veitch test, and 2 tons additional were supplied in order to put the soil in the best condition for crop growth. Rock phosphate was applied at the rate of

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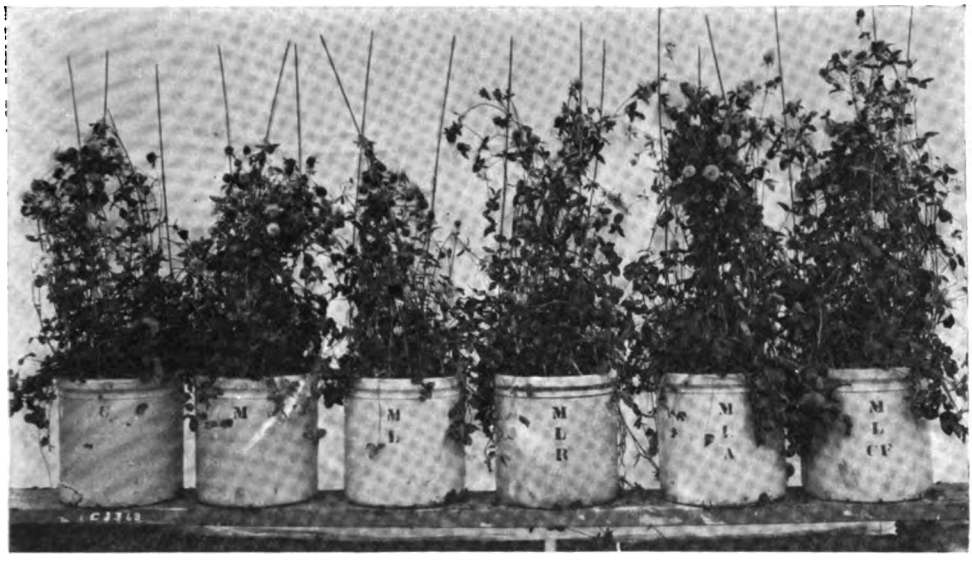

Fig. 2. Greenhouse experiment with clover in Tama silt loam in Marshall county.

2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of complete commercial fertilizer at the rate of 300 pounds per acre.

In the experiment on the Carrington loam from Bremer county, manure was applied at the rate of 10 tons per acre, lime as in the other tests, rock phosphate at the rate of 1,000 pounds per acre and acid phosphate at the rate of 300 pounds per acre. Wheat and clover were grown in all the experiments except on the Carrington loam from Bremer county, clover being seeded about one month after the wheat was up. In the experiment on the Bremer county soil, wheat alone was grown.

The results of the experiment on the Tama silt loam from Marshall county are given in table VII, the figures being the averages of the yields on the duplicate pots. Manure showed a very distinct effect on the wheat grown on this soil, but apparently had little influence on the clover. The application of lime in addition to manure had little effect on the wheat, but increased the clover yield. This is what would be expected, inasmuch as lime rarely increases the yields of grain crops, but the beneficial effects of the material are usually quite evident on the legumes grown in the rotation. Rock phosphate had little effect on the wheat, but showed some influence on the clover. Acid phosphate increased the wheat yield and brought about a considerable increase in the

TABLE VII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+lime	23.50	49.89
4	Manure+lime+rock phosphate	24.00	54.43
5	Manure+lime+acid phosphate	27.50	72.63
6	Manure+lime+complete commercial fertilizer	24.00	63.50

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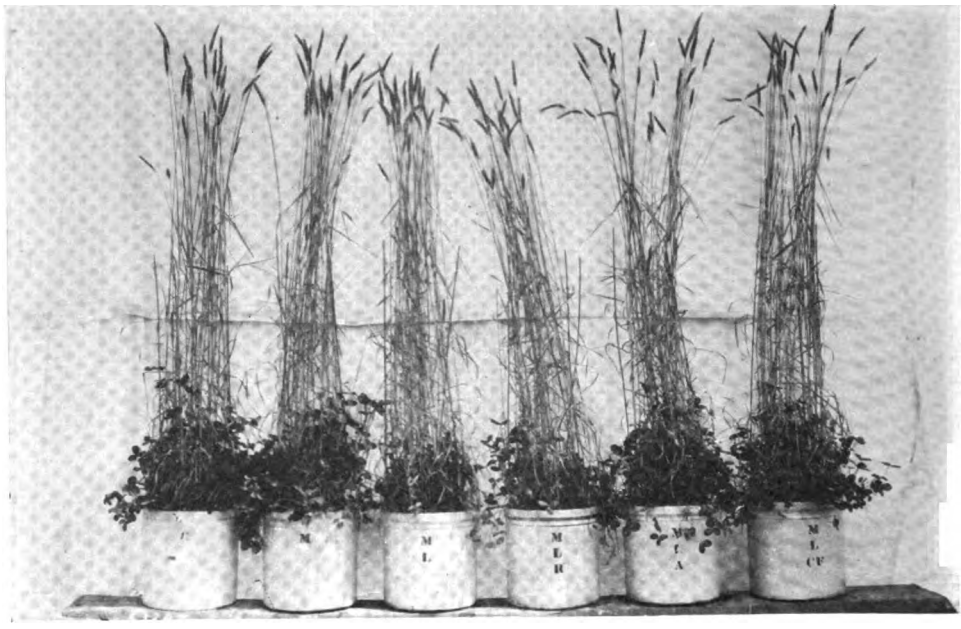

Fig. 3. Wheat and clover on Tama silt loam, Marshall county.

clover. The complete commercial fertilizer showed little effect on the wheat, but increased the clover yield. The increase was smaller, however, than that brought about by the acid phosphate.

It is apparent from these results that manure is a valuable fertilizing material for use on this soil and applications of this material should be made at regular intervals if crop yields are to be increased and the fertility is to be kept up. Lime should be applied when the soil is acid in reaction, if the best crops of legumes are to be grown. It seems quite probable that applications of phosphorus fertilizers would be of value on this soil, as is indicated by the effect of the acid phosphate, particularly. It may be noted that the acid phosphate showed up better than the other phosphorus fertilizers on both wheat and clover, the clover responding more definitely to the rock phosphate and complete commercial fertilizer, however, than did the wheat. It would evidently be very desirable for farmers to test the use of these materials on their own soils and determine the value of phosphorus and which particular phosphorus carrier would yield the greatest profit. No definite conclusions regarding the relative merits of these materials should be made from these greenhouse tests.

The second greenhouse experiment was on the Carrington loam from Marshall county. The results of this experiment are given in table VIII.

Again on this soil the beneficial effect of manure is shown very distinctly by the increased yield of wheat and the increased yield of clover. Lime in addition to manure had little influence on the wheat and the results for clover should not be considered, inasmuch as a slightly smaller yield is shown than with the manure alone. Evidently there was some disturbing factor in this particular case which reduced the clover yield. Rock phosphate, acid phosphate and the

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TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, MARSHALL COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	16.5	22.68
2	Manure	24.0	45.36
3	Manure+lime	25.0	40.82
4	Manure+lime+rock phosphate	27.0	49.89
5	Manure+lime+acid phosphate	27.5	54.43
6	Manure+lime+complete commercial fertilizer	26.0	49.89

complete commercial fertilizer all gave distinct increases in yields of both wheat and clover, there being very little differences between their effects in the case of the former crop. The acid phosphate showed up quite a little better with the clover. The results, however, would not warrant choosing between these phosphorus carriers and should not be interpreted too broadly.

It is evident that on the Carrington loam, as on the Tama silt loam, manure is an extremely valuable fertilizing material. Lime did not show up in this particular test, but there is abundant evidence to prove that this material will increase the yield of legumes in the rotation when applied to acid soils. Phosphorus fertilizers apparently may be used in some instances with profitable results. Just which material should be chosen must be determined for individual conditions.

The third experiment carried out on the Tama silt loam from Black Hawk county gives very similar results to those secured on the same soil type from Marshall county. The results of this experiment are given in table IX.

The results from this experiment indicate a very definite value from the application of manure, especially in the case of the clover crop, almost four

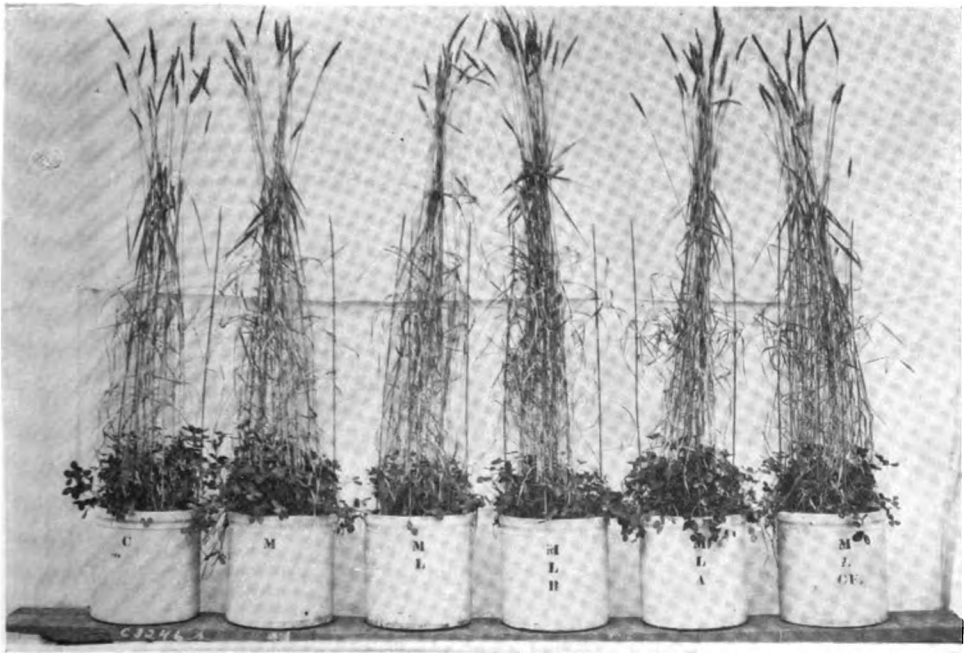

Fig. 4. Wheat and clover on Carrington loam, Marshall county.

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TABLE IX. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+lime	12.86	51.5
4	Manure+lime+rock phosphate	14.03	57.0
5	Manure+lime+acid phosphate	12.72	64.5
6	Manure+lime+complete commercial fertilizer	13.67	59.5

times as large a crop being secured when the manure was used. Little effect was shown on the wheat and the same is true of the application of lime. This latter material, however, as in the other experiment on the Tama silt loam, brought about a large increase in the clover crop. Rock phosphate increased the yield of wheat and likewise of clover. Acid phosphate had less effect on the wheat, but increased the clover crop considerably. The complete commercial fertilizer also increased the yields of both crops, showing more effect than the acid phosphate on the wheat, but less than the acid phosphate on the clover.

As was concluded in the earlier test, the application of manure to this particular soil is evidently a most desirable operation. Lime should be used when the soil is acid, and will undoubtedly benefit legumes. Phosphorus fertilizers might probably be applied with profit in many cases. Just when those materials should be used must be determined by experiments on individual farms.

The results of the fourth greenhouse experiment on the Carrington loam from Bremer county are given in table X.

These results again show very definitely the beneficial effect of applications of manure, the yield of wheat being more than doubled when manure was applied to this soil in addition to lime. Lime increased the wheat to a slight extent in this case, and the addition of phosphorus along with lime brought about further increases. When either acid phosphate or rock phosphate was used with manure, the rock seemed to be preferable, but when used without manure, acid phosphate gave the larger effects. It is apparent that the Carrington loam will respond to applications of manure and, when acid, lime will

Fig. 5. Greenhouse experiment with clover on Tama silt loam in Black Hawk county.

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TABLE X. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY

Pot No.	Treatment	Weight of wheat grain in grams
1	Check	8.25
2	Lime	9.25
3	Lime+acid phosphate	11.25
4	Lime+rock phosphate	9.50
5	Lime+manure	19.00
6	Lime+manure+acid phosphate	18.75
7	Lime+manure+rock phosphate	20.50

prove of value. Phosphorus fertilizers may prove profitable materials for use at the present time and will certainly be needed in the near future.

These greenhouse experiments as a whole indicate that the most desirable soil treatments for the Tama silt loam and the Carrington loam, the two major types in the county, consist in the use of manure and lime and probably phosphorus. Farm manure seems to be of especially large value and if this material cannot be applied in sufficient amounts, probably green manures should be used. Lime is of value when the soil is acid, particularly for the growth of legumes, and phosphorus fertilizers may be of value in some cases at the present time and will certainly be needed in the future. The kind of phosphorus fertilizers which should be used must be determined by the carrying out of special tests on individual soils and farmers are urged to test the use of these materials on their own soils on a small scale and, if favorable results are secured, the same materials may then be used on larger areas with the assurance of profit.

FIELD EXPERIMENTS

Several field experiments are just being started in Marshall county and it will be some time before the results secured on them will be available for publication. However, experiments have been under way for several years in nearby counties on the same soil types which occur most extensively in this county, and the results which are being secured on some of these fields will be included here, inasmuch as they undoubtedly indicate the nature of the results which may be expected from the experiments in Marshall county. The results of these experiments will serve to emphasize the needs of the soils of Marshall county and will also call attention to the desirability of testing certain fertilizing materials in the county and determining their value.

These field experiments are all planned with the idea of determining the relative value of various soil treatments and they are laid out on land which is entirely representative of the most important individual soil types in the county. They are permanently located by the installation of corner stakes and every precaution is taken in the application of fertilizers and in the harvesting of the crops to be sure that accurate results are secured. These fields include tests under the livestock and grain systems of farming, in the former, manure being applied, and in the latter, crop residues being utilized in place of the manure. Other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure has been applied in all cases at the rate of 8 tons per acre once in a four-year rotation. Limestone has been used in sufficient amounts to neutralize the acidity of the soil

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and supply 2 tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is used at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer has been used at the rate of 300 pounds per acre annually. These plots are 156 feet 6 inches by 28 feet in size, representing, therefore, one-tenth of an acre.

THE HUDSON FIELD

The Hudson field was laid out in 1917 on the Tama silt loam near Hudson in Black Hawk county. The results obtained on this field for 1918, 1919 and 1920 are given in table XI. Crop yields were not secured in 1921, owing to oversight on the part of the cooperator.

The results given in this table indicate quite definitely the beneficial effects of manure, lime and phosphorus fertilizers on the Tama silt loam. This is the same soil type which occurs on the major portion of the upland in Marshall county and conditions are so similar in the two counties that the conclusions from the experiment should be applicable to the same soil conditions in Marshall county. Manure seems to be of particular value on this soil for corn and oats and it is particularly interesting to note the beneficial effect of lime when applied to this soil along with manure. Rock phosphate, acid phosphate and a complete commercial fertilizer all brought about beneficial effects on these crops, the relative value of the three materials being somewhat different on the different crops and somewhat different on the same crop in different seasons. It is quite probable that phosphorus fertilizers may be used on this soil in many cases at the present time with beneficial effects and, while it is not possible to choose between the various phosphorus carriers from the results at hand, more complete data secured over a long period of years will undoubtedly show which phosphorus carrier is of the most economic value. The results serve to emphasize the recommendation that farmers test the use of these materials on small areas on their own farms and, if they prove of value, they may apply the same material to larger areas.

JESUP FIELD

The field experiment on the Carrington loam near Jesup in Black Hawk county was started in 1917 and the results are available for 1918, 1919, 1920 and 1921 on Series II and for 1918, 1919 and 1920 on Series I. In the latter series, the plots were in pasture during the season 1921 and hence no data is available. Both these experiments were carried out in the usual way and include thirteen plots in each series. Only the results of the livestock system

TABLE XI. FIELD EXERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Corn bu. per acre 1920
1	Check	45.8	47.6	53.2
2	Manure	49.3	54.7	62.8
3	Manure+lime	54.4	59.2	67.4
4	Manure+lime+rock phosphate	56.5	64.9	73.3
5	Manure+lime+acid phosphate	57.4	62.2	73.3
6	Manure+lime+complete commercial fertilizer	58.5	57.5	72.4

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plots are given, however, as the crop residues have not been sufficiently utilized as yet to exert any effect on the soil. The results of this experiment cannot be interpreted too broadly as yet, owing to the fact that there are some variations in yields such as are commonly obtained in the field. They do serve to indicate, however, the effects of fertilizer treatment on this particular soil and the conclusions drawn from them will undoubtedly prove applicable to Marshall county.

The results of this experiment are given in table XII and there is evidence of a beneficial effect of the application of manure on at least two of the crops. The yield on the check plot in 1919 was abnormal and hence conclusions cannot be drawn from the results secured. Lime in addition to manure had little effect on the corn, but did increase the clover and timothy. Rock phosphate showed a considerable effect on the corn and its effect was quite definite on the clover in 1920. There was little influence of this material, however, on the oats. Acid phosphate increased all three crops, showing the largest effect on the oats and on the timothy and clover. The complete commercial fertilizer showed the largest effect of all the treatments on the corn and on the oats, but had somewhat less effect on the clover and timothy than did the acid phosphate. Apparently manure and lime may be used on the Carrington loam with profit and there is evidence that phosphorus fertilizers may also prove profitable. The relative value of the different phosphorus carriers cannot be determined from these data. Further tests are necessary, but the evidence given serves to emphasize the need of testing phosphorus carriers on this soil in order to determine their value under special soil conditions.

The results obtained on Series II on the Jesup field are given in table XIII.

The results obtained in this experiment very largely confirm those obtained in Series I on the same soil. The application of manure brought about a rather definite increase in the yields of clover in 1919, clover and timothy in 1920 and corn in 1921. The application of lime showed some effect on the various crops grown, being particularly evidenced on the clover in 1920. The yield on the manure plot in 1919 was somewhat abnormal and hence the effect of lime does not show up in this particular season. Rather large influence was shown on the oats and some effect appeared also in the case of the corn. The application of rock phosphate showed little effect on any of the crops, but acid phosphate showed up very distinctly in the case of the clover in 1919. The complete commercial fertilizer likewise showed a distinct effect on the clover, both in 1919 and in 1920, the influence on the corn in 1921 being, however, very little different from that of the other phosphorus carriers.

TABLE XII. FIELD EXPERIMENT, CARRINGTON LOAM, BLACK HAWK COUNTY, JESUP FIELD, SERIES I

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Clover & timothy tons per acre 1920
1	Check	34.8	....	0.70
2	Manure	39.0	43.9	0.90
3	Manure+lime	40.4	43.5	1.10
4	Manure+lime+rock phosphate	52.7	40.5	1.57
5	Manure+lime+acid phosphate	50.3	52.4	2.20
6	Manure+lime+complete commercial fertilizer	59.2	58.9	2.00

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TABLE XIII. FIELD EXPERIMENT, CARRINGTON LOAM, BLACK HAWK COUNTY. JESUP FIELD, SERIES II.

Plot No.	Treatment	Oats bu. per acre 1918	Clover tons per acre 1919	Tim'thy & clover tons per acre 1920	Corn bu. per acre 1921
1	Check	71.9	1.17	0.50	58.7
2	Manure	71.6	2.08	0.85	72.8
3	Manure+lime	83.1	1.92	1.20	77.6
4	Manure+lime+rock phosphate	81.8	1.86	1.15	78.1
5	Manure+lime+acid phosphate	76.1	2.22	1.12	75.5
6	Manure+lime+complete commercial fertilizer	77.2	2.80	1.25	78.7

Apparently the application of manure is of particular value on the Carrington loam and the use of lime when the soil is acid may bring about a distinct effect on the legumes of the rotation. Phosphorus carriers may prove of value on this soil and their effects may appear on any of the crops grown, showing up more definitely on clover, particularly in the case of acid phosphate. The suggestion that farmers test the use of various phosphorus materials on this particular soil type is emphasized by these results and it is apparently quite desirable that they determine by special tests what phosphorus carrier should be used on their particular soils.

These field experiments as a whole serve to confirm the results obtained in the greenhouse tests, showing the value of manure and lime on the Tama silt loam and the Carrington loam, the two main types in the county, and the possibility of the value of phosphorus fertilizers on these soils.

THE NEEDS OF MARSHALL COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

Field experiments have just been started on some of the main soil types of Marshall county and there is no data available as yet from these tests showing the value of various fertilizer treatments. The field experiments from Black Hawk county which are included in this report, however, are located on the same types which are most extensive in Marshall county and hence the results of those experiments may be considered to indicate rather definitely the results which may be secured in Marshall county. After the experiments in this county have been under way for a period of years, they will be published in a supplementary report and it will then be possible to draw more definite conclusions regarding the most economic treatments for the various soil types. For the present, the suggestions which are made as to desirable treatments are based only on the results of the laboratory and greenhouse tests and on the field tests of the same soil types in Black Hawk county. However, no definite recommendations are made in this report which have not been tested to some extent by individual farmers and have been proved valuable, therefore, by practical experience.

It should be emphasized that individual farmers may carry out tests on their own farms with certain fertilizing materials and determine their value. In

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this way the farmer may secure very definite information regarding the desirability of using the various fertilizing materials on their own soils. Furthermore, the information which is secured in this way is of considerable value to a solution of the problem of fertilization of the same soil types elsewhere. This suggestion is often made and many farmers are now conducting tests on a small scale which are giving them results of much interest and value. These tests are not complicated and may very readily be planned and carried out. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid and assist farmers who wish to carry out tests of various materials. Until the field experiments now under way are more complete and the results conclusive, the best suggestion which can be made is the testing of various materials on small areas. The additional suggestions which are given in the following pages are only those which are of value as shown by practical experience and that may be put into operation under any farm conditions.

LIMING

The soils of Marshall county are very largely acid in reaction and, therefore, in need of lime. None of the major soil types in the county contain any quantity of bases or inorganic carbon, as will be seen from a consideration of the tables given earlier in the report. In fact, there is only one type in the county which is high in inorganic carbon content and this type, the Lindley loam, is of very minor importance. Three other soils do not give an acid reaction in the surface soil, but the content of basic material is so small that the amount present will soon be exhausted and the soils will soon react acid. Two of the soil types which react acid in the surface soil give a basic reaction in the subsurface and subsoil, but in these cases, also, the amount of lime present is so small that the soils will soon be in need of limestone. These are also minor types in the county.

It is apparent that the needs of the surface soils may be taken to show the lime requirement of the soils and that little attention need be paid to the subsoil conditions. In fact, the presence of small amounts of lime in the subsoil is of little significance, inasmuch as lime rarely moves upward in the soil, but tends rather to be washed out quite rapidly in the drainage water. The results of the analyses certainly indicate that in general the soils of the county are in need of lime, and tests should be made at regular intervals in all cases if the soil reaction is to be kept satisfactory for crop growth.

It should be understood that the results given in the tables are not applicable to all areas of the various soil types, but are merely indicative of the needs of the individual soil types. Soils vary widely in lime requirement, and even the same soil type may show a quite variable need for lime. Hence the figures given should not be interpreted too broadly. Before lime is applied to any soil, a test should be made of the particular soil in order that the application of lime may be sufficient and in order to avoid the addition of too small an amount. Farmers may test their own soils for acidity or lime requirements, or they may send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. By doing this they will insure the use of the proper amount of lime and they will also insure the best

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reaction in the soil for the growth of general farm crops, particularly legumes. Clover and alfalfa are especially sensitive to lack of lime in the soil and will not make a satisfactory growth on acid soils and in many cases increases in other crops are secured when lime is applied to acid soils.

The results obtained on the soils of Marshall county indicate, therefore, that all the soils of the county should be tested for acidity and lime applied as shown to be necessary, if the best crop growth is to be secured. When soils are cultivated there is a continual loss of lime thru utilization by crops and particularly thru leaching or washing away in the drainage water. If the soil is well drained, as is absolutely necessary, of course, if the soil conditions are the most satisfactory for crop growth, the loss of lime by drainage may be considerable. The texture of the soil is also of significance and light soils lose their lime content much more rapidly than heavier textured types. In all cases, however, where crops are grown, lime gradually disappears and hence one test for acidity, one application of lime to a soil, will not be sufficient for all time. Tests must be made at regular intervals and lime applied as needed, if the soils are to be kept in the best reaction for crop growth. It is suggested that probably a test once in a four-year rotation is sufficient and that lime should be applied preceding the clover crop of the regular four-year rotation. This is due to the fact that the clover or any other legume in the rotation will be benefited to the largest extent by the application of lime. Other crops of the rotation may show an indirect benefit from the use of lime, but the effect on corn, oats and other small grains is usually of less importance than the effect on clover or alfalfa.

Many tests under farm conditions have shown the benefits to be derived from liming. The experiments referred to in the preceding pages emphasize the importance of lime on acid soils if legume crops are to be grown satisfactorily. It is quite evident from much practical experience and from considerable experimental data, that liming is a profitable practice, even if the clover crop alone is considered. When the secondary effects of lime on corn and small grains are taken into account, the economy of adding lime to acid soils is quite apparent. The value of the increased crop growth more than offsets the expense of the application. The farmers of Marshall county may be assured that applications of lime to their soils, when acid, will give them profitable returns. They should see to it that their soils are tested, especially if legumes are to be grown, if they hope to secure satisfactory yields. Further recommendations regarding the use of lime on soils, losses by leaching and other information connected with liming are given in Bulletin 151 of the Iowa Agricultural Experiment Station. The list of the companies from which the material may be secured and the cost of the same are given in Circular 58.

MANURING

Many of the soils of Marshall county are rather poorly supplied with organic matter and there are few instances where additions would not be of value at the present time. Manuring is perhaps the most important farm practice for the soils of this county and the results secured from the use of manure are

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very definite. There is no other fertilizing material which has given anything like as large effects on crop growth as has farm manure. The practical experience of many farmers in the county and the experiments reported in the preceding pages are in entire agreement in showing the large crop increases secured from the use of farm manure. On those soils which are particularly low in organic matter, as shown by the analyses, manure gives especially large returns. Such effects are noted on the sandy soils in the county or the lighter textured types, but even on those types which seem to be fairly well supplied with organic matter, crop yields are increased to a large extent by the use of farm manure. The Tama silt loam, for example, is not particularly deficient in organic matter; in fact, it shows a content which is almost as high as any type in the county and yet the application of manure has quite consistently given increased crop yields. Every farmer in Marshall county should see to it that the manure produced on his farm is carefully preserved and applied to the soil, if satisfactory crop growth is to be secured and the soils kept permanently fertile.

Manure benefits soils because of its action on the chemical, physical and bacteriological conditions. It adds plant food constituents to the soil, returning, as it does, a large part of the plant food which has been removed from the soil by crops which have been utilized for feed. Hence manure will lengthen the life of the soil or, in other words, prolong the time until any of the essential plant food constituents become deficient. Manure improves the physical condition of soils, whether heavy or light. It opens up heavy soils and makes them less impervious and better aerated and permits of the removal of excessive moisture. It makes light soils more retentive of moisture, less open and porous and less subject to losses by leaching. By its physical effect on soils, manure exerts a secondary chemical effect in that more available plant food is produced and crops are better supplied with necessary food constituents. Applications of manure to the soil mean also the addition of enormous numbers of bacteria which are contained in the manure, and these bacteria have a distinctly beneficial effect, due to their ability to transform unavailable plant food into an available form. The improved physical conditions stimulate bacterial action, and greater bacterial action means more plant food and hence better crop growth. There are undoubtedly many instances where the bacterial effects of manure are of major importance. On soils which are rather well supplied with organic matter, it seems probable that the bacterial effects of manure are of much significance. Perhaps this is the reason for the very distinct effect in the case of the Tama silt loam. On most soil types, however, when increased crop yields are secured from the use of manure it is probably because of a combination of bacterial, chemical and physical effects. There are, of course, instances where the actual addition of plant food would be of the greatest importance, but in general for Marshall county soils, the effect of manure is undoubtedly attributable to improved physical conditions for plant growth and a better production of available plant food.

The beneficial effect of manure is shown in the case of general farm crops and it is usually conceded that no other fertilizing materials will prove of as large value if manure is not applied with them. The fertilization of the soils

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of the county should, therefore, begin with the use of manure and, if other fertilizers are employed, they should be used in addition to manure if economic results are to be secured. This statement applies, of course, only to livestock farming conditions and if manure is not available on the farm, other sources of organic matter must be employed, as will be noted later.

The value of manure as a fertilizer for general farm crops is so large that the importance of preserving the manure produced on the farm to permit of its exerting the largest possible effects is quite evident. If manure is stored in loose heaps and exposed to the weather and to the leaching actions of rains, it may lose from 70 to 90 percent of its valuable material. Under such conditions the application of manure will not bring about the large effects on crop growth which may be secured from the properly stored material. Hence, the improper storage of manure may lead to actual economic loss on the farm. The farmer who is not preserving the valuable portion of the manure produced on his farm is decreasing his crop yields and hence reducing his income. There are various ways in which manure may be stored to prevent the loss of valuable material and no one method can be suggested for all conditions. It may be stored in a covered yard or pit and protected from the weather, or it may be composted, but whatever method is used, it is particularly important that the manure be kept moist and compact and protected from the weather.

It may be possible in some cases to apply the manure as produced, to the soil. In such cases there is, of course, no storage problem. There are, however, many instances where such a method of application is not possible or desirable and then some method of storage must be selected which will permit of the securing of the largest possible beneficial effects from the application of the material. It is estimated that when manure is applied as produced, or when it is carefully stored before application, it may return to the land 75 to 80 percent of the plant food which has been removed from the soil by the crops grown, and it is up to the farmer to see to it that none of the valuable material contained in the manure is allowed to escape from the farm.

The production of manure on the average livestock farm is unfortunately quite insufficient in most cases to permit any large application to all the soils of the farm. The usual application is 8 to 10 tons per acre once in a four-year rotation. Larger applications than this are sometimes made on very light textured soils for certain crops, but for general farm crops it is usually not desirable to apply more than 16 to 20 tons per acre. Only in cases where truck crops are to be grown should larger applications of manure than this be applied and even here extremely large applications are not always desirable or necessary, and it should be remembered that if very large applications are made to one field the remainder of the farm may suffer, so it is well to take care that applications of manure are made at regular intervals and in reasonable amounts, if the growth of general farm crops is to be satisfactory and all the soils of the farm are to remain productive.

Even on the livestock farm there is not sufficient manure to maintain the supply of organic matter and nitrogen in the soil and on the grain farm, of course, some other material must be utilized in place of farm manure. In both instances, green manuring is a practice which should be followed, either as a

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supplement to manuring or as a substitute for that practice. Leguminous crops are the most desirable for use as green manures because of the fact that when well inoculated they possess the ability to take up nitrogen from the atmosphere and fix it in the soil, where it may be utilized by subsequent crops. Such crops not only keep up the supply of organic matter, but they also act as nitrogenous fertilizers. Nonlegumes, on the other hand, do not increase the nitrogen content of the soil, but merely build it up in organic matter. When organic matter is low in soils, however, the nitrogen content is usually low also and hence there are few instances when leguminous crops would not be more desirable for use as green manures than non-legumes. There are many legumes available for use under a wide variety of conditions, and some one may be chosen which will fit in with almost any rotation. Green manuring undoubtedly may be practiced profitably in some cases in Marshall county where the supply of farm manure is limited and the soils are particularly deficient in organic matter. The practice, however, should not be followed blindly or carelessly because of the fact that undesirable effects may result if the conditions are not such that rapid decomposition will follow the plowing under of the crop. When soils are dry, for example, green manuring should not be practiced, as there may be a detrimental interference with the moisture conditions. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

The proper utilization of all crop residues, such as straw and stover, is very important if the organic matter content of the soils of the county is to be kept up. These materials are frequently burned or otherwise destroyed and when this occurs there is a large loss of valuable material and the farmer is actually throwing away valuable fertility constituents. Such materials may be used on the livestock farm for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil, or they may be stored under proper conditions and allowed to decompose partially before they are applied. On the grain farm the return of all crop residues is of particular significance, owing to the lack of manure, but these materials should be quite as carefully used on the livestock farm in order to supplement the manure. Crop residues not only supply organic matter to the soil but they also add plant food constituents and hence actually lengthen the life of the soil. Many times crop residues have been found to exert distinctly beneficial effects on crop growth and they should be considered as valuable supplements to manure and green manures if soil conditions are to be kept most satisfactory for crop growth.

THE USE OF COMMERCIAL FERTILIZERS

The results of the analyses of the soils of Marshall county which have been given earlier in this report show quite distinctly that phosphorus is not present in any considerable amounts in any of the types and in most cases the amount present is so low that phosphorus will certainly be needed on these soils in the near future if, indeed, phosphorus fertilizers would not prove profitable for use at the present time.

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There is always a possibility, where the total supply of phosphorus is as low as is the case in some of these soils, that the amount of available phosphorus present will be insufficient to permit of the most satisfactory crop growth. The greenhouse experiments and the field experiments on two of the important soil types in an adjacent county indicate that phosphorus fertilizers may be used at the present time with value, at least in some cases. The results of the greenhouse experiments are, of course, merely indicative of what may occur in the field, but it is usually true that the indications from the greenhouse tests are borne out by later field results. The results of the field experiments which are reported on two soil types from Black Hawk county are undoubtedly applicable to the same soil conditions in Marshall county, and it may safely be concluded that phosphorus will be needed on these soils in the near future and may show profitable returns even at the present time.

It is not possible, furthermore, from the experiments which have been discussed to draw definite conclusions regarding the particular phosphorus fertilizer which should be used in any case. Acid phosphate or rock phosphate may be employed, and the former frequently gives the larger returns. In other cases, however, rock phosphate proves of more economic value. Acid phosphate is more expensive than rock phosphate, but it contains phosphorus in an available form and hence this element is more readily utilizable by crops. On the other hand, rock phosphate has a low rate of availability and considerably larger applications must be made. A choice between these two phosphorus carriers must depend, therefore, upon the cost of the actual application, the value of the crop increases secured from the use of the material and upon the results secured for at least one rotation. It is necessary to take the yields for at least four years in order that opportunity may be given for the utilization of the rock phosphate to the best advantage. This material is applied but once in the rotation, while acid phosphate is added annually. The experiments which have been begun in Marshall county and those which are under way in Black Hawk county on the same soil types will yield definite information along this line at a later date. The results of these field experiments, when they are more complete, will be published in later reports. At the present time sufficient results have not been secured to permit of definite conclusions. It can only be recommended, therefore, that farmers test these two phosphorus fertilizers on their own soils and determine for their own conditions which material will yield the larger value. It is not a difficult matter to test these materials on the farm and directions which may be readily followed in conducting such tests are given in Circular 51 of the Iowa Agricultural Experiment Station. If one of these fertilizers shows profit according to a test on a small area, then the same material may be used on a large area with the assurance of profit. Farmers in Marshall county who are interested in increasing their crop yields and building their soils up in fertility, are urged to test the use of phosphorus on their own farms and determine the value of phosphorus fertilizers for their particular conditions.

Some of the soil types in Marshall county are apparently well supplied with nitrogen, but in other cases the amount of this element present in the soil is too low for the most satisfactory crop growth. Even on the better supplied

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types, however, the amount of nitrogen present is insufficient for the continuous growth of satisfactory crops over a long period of years. In planning systems of permanent fertility for the soils of the county, the maintenance of the supply of nitrogen in the soil should not be disregarded, even on those types which are apparently well supplied. There is a continual removal of nitrogen from soils by cropping and, on the better types which are well drained and in the best physical condition for crop growth, there may be a considerable removal in the drainage water. It is essential, therefore, that some nitrogenous material be used on all the soils of the county in order to keep up the supply.

The proper preservation and application of farm manure will insure the return of a large portion of the nitrogen removed from the soil by the crops grown and may keep the loss of this constituent down to a small amount. On the livestock farm, therefore, the maintenance of the nitrogen supply is much more readily accomplished than on the grain farm because of the manure which is available for use. It is impossible, however, to keep up the supply of nitrogen by the use of farm manure alone, even on the livestock farm, owing to the fact that the amount produced on the average farm is insufficient to provide for all the soils of the farm. Hence this material must be supplemented on the livestock farm and something must be substituted for it on the grain farm. Leguminous green manures are the cheapest and the most efficient nitrogenous fertilizers which may be employed. Every rotation should contain a legume and if this legume is inoculated as it should be, there may be an addition of nitrogen to the soil, owing to the fact that the inoculated legume draws a large part of its nitrogen from the atmosphere. When the leguminous crop is removed from the soil, there is, of course, in most cases, no addition of nitrogen, and if the soil is to be built up in nitrogen, a part or all of the legume crop must be turned under as a green manure in order to increase the nitrogen content of the soil. The removal of the legume crop would probably not reduce the nitrogen content of the soil to any extent, but if it is to really serve as a nitrogenous fertilizer, it must be handled as a green manure crop. If the seed only of red clover is removed and the remainder of the crop is turned under in the soil, the crop may serve to bring about very desirable effects as a green manure and increase to a considerable extent the nitrogen content. Legumes may also be used in the rotation as catch crops, in which case they may supply considerable nitrogen as well as organic matter to the soil. There are undoubtedly some cases in Marshall county where the utilization of legumes as green manures would be desirable from the standpoint of building up the supply of nitrogen. The proper utilization of crop residues on all farms aids materially in cutting down the losses of nitrogen and they are a valuable supplement to farm manure and green manures.

Commercial nitrogenous fertilizers may be utilized in small amounts as top dressings to encourage the early growth of certain crops, but their use for general farm crops on the soils of the county cannot be recommended at the present time. If they prove of value on small areas for certain crops, they may be used without fear of injuring the soil, but leguminous crops as green manures are undoubtedly a cheaper and more generally satisfactory source of nitrogen.

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Earlier tests of the soils of the state have shown a large amount of potassium in all cases and there is no doubt but that the soils of Marshall county are in general very well supplied with this element. There is enough present to provide for crop production for many hundreds of years, provided it is made available sufficiently rapidly. It seems unlikely, therefore, that potassium fertilizers would prove of value on the soils of the county. They might be used in small amounts as top dressings to stimulate the early growth of some crops, but their use for general farm crops could not be recommended now. If any farmers are interested and wish to test these materials on small areas they may readily determine whether or not the materials will give profitable returns. If they show value on small areas they may be used on larger areas without any injury to the soil. It should be emphasized that it is very important to keep the physical condition of the soils satisfactory for the production of available plant food in order that available potassium may be supplied in sufficient amounts to permit of the best crop growth. It is particularly important that the soils be well drained and cultivated and that they be well supplied with organic matter. When these conditions are observed there should be a sufficient production of available potassium from the store already present in the soil so that additional applications will not prove necessary.

Experimental work now under way includes the testing of certain complete commercial fertilizers and if farmers are interested in any particular brands, they may test them on small areas on their own farms and determine their value. For the present, no definite recommendations regarding the use of these materials can be made. They have not yet shown economic returns in comparison with phosphorus carriers according to the field data which is available and it is considered extremely unlikely that they will prove as economic as phosphorus fertilizers, owing to the fact that the nitrogen which they contain may be more cheaply supplied by the use of legumes, and the potassium present in them is not needed. In the course of the next few years results will be available which will show definitely the relative value of complete fertilizers in comparison with acid phosphate and rock phosphate, but for the present they cannot be recommended for general farm use in Marshall county. They should certainly not be used on large areas until tests have been carried out on a small scale and their value definitely proved for the particular conditions and especially their superior value over phosphorus carriers. There is no objection to the use of complete commercial fertilizers as far as the soil is concerned and the chief factor to be considered is their economic value in comparison with phosphorus fertilizers.

DRAINAGE

Marshall county is quite adequately drained in most parts, as has already been noted, and the drainage map which is given earlier in this report gives a rather definite idea of the drainage system of the county. There are very few cases, therefore, where artificial drainage is necessary, but in some instances the installation of tile would be of value in increasing crop production.

The Clyde silty clay loam and the Bremer silty clay loam of the upland and terrace are poorly drained and the Wabash silty clay loam of the bottom

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is likewise poorly drained. This type is also subject to overflow and the same is true of the Wabash loam and the silt loam. In the case of all these types, proper drainage would be of value in increasing their productivity. No other soil treatment will prove of value if the soil is poorly drained and the first treatment needed to insure satisfactory crop production is to take care of the drainage of the soil. Even tho tiling may be somewhat expensive, the expense is more than warranted by the returns which are secured in the way of better crop growth. Besides the soil types mentioned, there may be areas in the county of certain other types which would be benefited by the installation of tile. In general it may be said that any of the soils of Marshall county which are poorly drained should be tiled out if the best crop yields are to be secured.

THE ROTATION OF CROPS

It is a well known fact that the natural fertility of soils is rather rapidly reduced by the continuous growing of any one crop. In fact, continuous cropping will bring about a reduction of fertility in the soil much more rapidly than when a rotation is used. Even if the particular crop which is grown continuously is of considerable value, the income from the land over a period of years will be greater when a rotation is followed. Apparently the use of some rotation is absolutely necessary if the soil is to be kept permanently in a fertile condition.

Just what rotation should be followed must be determined by the local conditions and no one rotation can be recommended as desirable under all circumstances. It should be emphasized, however, that any rotation should contain a legume and likewise the most profitable crops of the region. No rotation experiments have been carried out in Marshall county. The following are given, however, as examples of rotations which are of the most common use in the state and have proved quite satisfactory.

1. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy).
Fourth Year—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

2. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years, and the fields should then be used for the four-year rotation outlined above.)

3. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain).
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

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Fig. 6. Serious washing often occurs in draws in the Carrington loam in Marshall county.

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will, of course, wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion, while heavy soils, such as loams, silt loams and clays, may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or, if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and the absorption of water is very slow will spring plowing be advisable. The organic matter content of soils

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should be kept up by the addition of farm manure, green manures and crop residues, if soil subject to erosion is to be properly protected. By the use of such materials, the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but it is less harmful and is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Marshall county erosion occurs to a considerable extent in the areas of Shelby loam, Clinton silt loam and Lindley loam. In some instances serious washing has occurred in some of the other soil types, and wherever any removal of surface soil thru this destructive actions occurs, some means of prevention or control should be adopted.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and, in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There

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are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainage-ways and may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways, but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch, but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

"Staking In." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case, consists in using the brush without stakes. The brush is cut so that a heavy branch, pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away readily by the action of a large volume of water. A series of these brush-piles may be installed up the course of the gully and, with the regular repair of washouts or undercuttings, may prove very effective.

The modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of 4 to 10 feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend, of course, upon the size of the gully. These posts should be set well into the ground and spaced about 4 feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully,

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but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale, because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided, the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends 2 or 3 feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters, and the dam should be supplied with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully, and higher in the center than at the sides, to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey Dam. In fact, the principle of construction is identical, but in some sections the name "Adams dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints, and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an upstream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams, the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

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The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed, and a great variety of materials may be employed. The results are in the main rather unsatisfactory, and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish, even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven-Wire Dam.—The use of woven wire, especially in connection with brush or rubbish, has sometimes proved satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches, and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and, for quick results, sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. It is, however, rather expensive. Then, too, it may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to the high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage, properly installed. This removal of water to the depth of the tile increases the water-absorbing power of the soil and thus decreases the tendency toward erosion. Catch wells properly located over the surface, and consisting of depressions or holes filled with coarse gravel and connected with the tile, help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey or Adams dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

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BOTTOMLANDS

Erosion frequently occurs in bottomlands and, especially where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in any community and, while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows, which extend up the drainage channels. While the method has some good features, it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general, it may be said that in pastures, bottomlands and gulches the presence of trees may be effective in controlling erosion, but a row of trees across cultivated land, or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed, if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years, is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope, or at an angle to it, is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proved quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall-plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

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Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion, as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil may be thereby reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value, both in increasing the feeding zone of plant roots and in making the soil more absorptive, and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN MARSHALL COUNTY*

There are fifteen soil types in Marshall county and an area of muck, making a total of sixteen separate soil areas. These are divided into four large groups, according to their origin and location, and these groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are five drift soils in the county, which belong in the Carrington, Shelby, Lindley and Clyde series, and together they cover 19.8 percent of the total area of the county.

CARRINGTON LOAM (1)

The Carrington loam is the most extensive drift soil, covering 10.2 percent of the total area. It occurs mainly in the western part of the county, in an irregular shaped area extending from the northern boundary, where it is over two miles wide, to a narrow point near the southern boundary. It takes up practically half of Liberty and Minerva townships and a large part of State Center township. It also occurs in narrow areas along the streams and intermittent drainageways in the northeastern part of the county. In this part of the county it is found chiefly along Chicken creek, Asher creek, Little Asher creek, Burnett creek and Devil's Run, and separates the loessial upland of the Tama series from the Wabash bottoms. In its extensive area in the western part of the county it occurs almost continuously, being dotted with small areas of the Clyde silty clay loam and cut in some instances by areas of Wabash loam and Wabash silt loam along the streams.

The surface soil of the Carrington loam is a dark brown heavy loam, 8 to 10 inches in depth. In the flatter areas it is almost black in color and frequently extends to greater depths. The subsoil is a brownish-yellow heavy loam to clay loam, somewhat gritty in texture. There is no sharp line of division between the surface soil and the subsoil, the former gradually passing into the lighter-colored, heavier-textured subsoil. Boulders occur on the sur-

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

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Fig. 7. The Carrington loam topography is very much like the gently rolling Tama.

face and thru the soil section, but they are not present in large enough numbers to interfere seriously with cultivation.

In topography the Carrington loam in the western part of the county is gently rolling to rolling. In the narrow areas northeast of the Iowa river the topography is moderately sloping, and the soil in these areas is modified to some extent by the loessial material from the Tama uplands. The type is generally well drained and is not in need of tiling. In some areas, particularly in the northeastern part of the county, erosion has occurred to some extent and control measures are necessary.

About 95 percent of this type is now under cultivation, the rest being in permanent pasture and farmsteads. Corn is the most important crop, about one-third of the type being used for its production. Average yields of about 45 bushels per acre are obtained and in many cases where the soil has been carefully treated, much higher yields than this are secured. The major portion of the corn produced is fed to hogs and the same is true of oats, which is the second crop in acreage. Yields of oats range from 35 to 40 bushels on the average. Clover and timothy do well and yield 1½ to 2½ tons per acre. Wheat, barley and rye are relatively unimportant crops on this type. Alfalfa is grown only in an experimental way. A few potatoes are produced for home consumption and some sorghum has been grown.

The Carrington loam is a relatively fertile soil, but it would be benefited considerably by better soil treatments. It is acid and should be limed if satisfactory crops, particularly of legumes, are to be secured. It is not particularly high in organic carbon or nitrogen and applications of farm manure have been found to bring about large increases in crop growth. The field experiments and the greenhouse tests, described earlier in this report, and much farm experience have shown rather considerable effects from the use of farm manure on general farm crops. If farm manure is not available in sufficient amounts, leguminous green manures would improve the nitrogen

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and organic matter content of this soil and make it more productive. The phosphorus supply is rather low and applications of phosphorus fertilizers would undoubtedly prove of value in some cases. This is also indicated in the field and greenhouse tests. Just which particular phosphorus carrier should be used must be determined by special tests. Where the soil has been subject to erosion, methods for the control and prevention of this destructive action should be taken. With these treatments as suggested, the Carrington loam may be made more productive than it is at present and large crop yields may be insured for future years.

SHELBY LOAM (79)

The Shelby loam is a minor soil type in the county, covering 7.0 percent of the total area. It occurs in narrow areas in various parts of the county along many of the streams. It is found principally in the southern half of the county, altho there is a rather extensive area in Marion township along Rock creek and Nicholson creek. In most cases it separates the Tama silt loam of the upland from the Wabash silt loam of the bottoms, altho there are many areas where it occupies intermittent drainageways completely and no bottomland is found.

The surface soil of the Shelby loam is a medium brown to dark brown silty loam. At a depth of 8 inches, on the average, the soil passes into a yellow gritty, silty clay loam or clay loam. In some instances the subsoil is a stiff, tenacious, reddish-brown clay. Considerable gravel and some boulders occur over the surface of the type and frequently thruout the three-foot section, but not in sufficient numbers to interfere with cultivation.

In topography this soil is rolling, and it is subject to destructive erosion. Gullies 10 to 15 feet in depth are quite common and, unless controlled, these gullies may increase rapidly and extend back into the loess covered uplands.

About 45 percent of the Shelby loam is under cultivation, the remainder being very largely in permanent pasture. The same crops are grown as on the Tama silt loam, but the yields are lower, corn giving 25 to 35 bushels, oats 25 to 30 bushels and clover and timothy 1 to 1½ tons per acre.

The Shelby loam is mainly in need of protection from erosion, if it is to be kept in cultivation and satisfactory crop yields are to be secured. It is acid in reaction and in need of lime, especially if legumes are to be grown. It is relatively low in organic matter and nitrogen, and applications of farm manure have proved of large value. Green manures might be used in place of farm manure in many cases, not only to increase the fertility of the soil, but to aid in preventing its washing away. The phosphorus supply is not high and the soils will need some phosphorus fertilizer in the near future. It is probable, however, that in many instances phosphorus fertilizers will prove of value now.

LINDLEY LOAM (65)

The Lindley loam is a minor type in the county, covering only 1.0 percent of the total area. It occurs entirely in the southwestern part of the county, in association with the Clinton silt loam and the Tama silt loam. It is found along Clear creek, separating the Tama and the Clinton upland soils from the Wabash bottoms.

The surface soil of the Lindley loam is a light brown to light grayish loam and it extends to a depth of 6 inches on the average. At that point it passes

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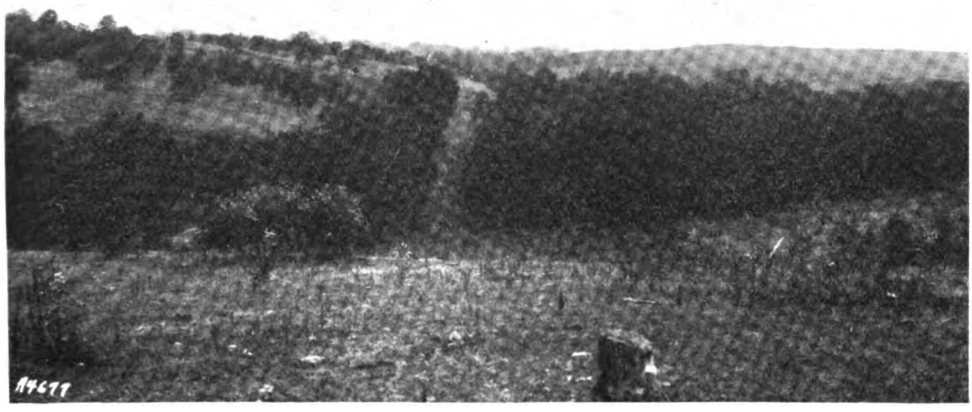

Fig. 8. Rough topography characteristic of the Lindley loam in Marshall county.

into a yellow loam to clay loam subsoil. Gravel occurs both in the surface soil and in the subsoil.

In topography the Lindley loam is rolling to rough, lying on the steep slopes along the drainageways. It is thoroly drained, except in a few instances. It is subject to erosion and destructive washing has prevented its cultivation.

This type was originally forested with oak, elm, sumac and hazel brush and much of it is still in woodlots and permanent pasture. When the topography is favorable for cultivation, oats, corn and clover may be grown successfully. The soil, however, is extremely low in organic matter and nitrogen and applications of farm manure or leguminous green manures are very desirable if satisfactory crop yields are to be secured. It is not acid in reaction and contains a rather large amount of carbonates. The phosphorus supply is not high and phosphorus will be needed in the future, altho it is a question whether any phosphorus fertilizer would prove of value on the type at the present time. It should be protected from washing and in many areas it will probably prove most satisfactory to keep it in pasture.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a minor type in the county, covering only 0.9 percent of the total area. It occurs in several areas on the slopes, between the stream terraces or the first bottoms and the higher silty loessial upland. The largest area is found along Minerva creek two miles west of Albion. Smaller areas are found south and east of Albion and east of Clemons. Other small areas occur along the Iowa river, Honey creek, Asher creek and Minerva creek.

The surface soil of the Carrington fine sandy loam is a dark brown fine sandy loam, 10 to 15 inches in depth. The subsoil is a brownish-yellow to yellow

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Fig. 9. Erosion occurs extensively in the Lindley loam.

fine sandy loam, very open and porous in structure. Boulders are scattered over the surface of the soil.

In topography the type is gently rolling to rolling. It is subject to drouth, owing to the open sandy texture of the subsoil. It is not gullied or eroded to any extent and, when properly handled, may be utilized for the growth of general farm crops.

About 85 percent of the type is utilized for crop production at present and corn is the principal crop grown. Average yields of 30 to 35 bushels per acre are secured and these yields may be increased considerably under favorable conditions. Oats are grown to some extent and yield from 30 to 35 bushels per acre.

This soil is acid in reaction and would respond to applications of lime. It is in need of organic matter, and additions of farm manure would prove of large value. Leguminous green manures would also prove of value in many cases, especially where applications of farm manure are necessarily limited. It is low in phosphorus and, for the growth of general farm crops, applications of phosphorus fertilizers would undoubtedly be of value. It is particularly necessary on this type that the organic matter supply be increased in order to protect the crops during periods of drouth.

CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is a very minor soil type in the county, covering only 0.7 percent of the total area. It occurs in small areas, chiefly in the western part of the county. There are a few small areas in the northeastern part of the county and a few areas along Minerva creek, in the center of the county. In general, however, this type is confined to the western part of the

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county and is associated with the Carrington loam. It is found in depressions in the upland and in a few areas along intermittent drainage lines.

The surface soil of the Clyde silty clay loam is a black silty clay loam, 15 to 18 inches in depth. This is underlaid by a light gray silty clay loam, mottled with brownish-yellow and rusty brown. The surface soil is plastic and sticky when wet and hard when dry. In the areas surrounded by the Carrington fine sandy loam, the surface texture has been modified by sand washed upon it and sometimes is a light loam to sandy loam.

In topography this type is level to depressed, and it is very poorly drained. Most of it is used for pasture and hay. Where it has been drained, however, it provides excellent farm land and is well adapted to corn, average yields of 50 bushels per acre being secured. Oats do not do well on the soil, as they are apt to lodge before ripening. It is well adapted to grasses, and timothy and red clover grow very satisfactorily when the soil is drained. Yields of hay ordinarily average ½ to 2½ tons per acre.

As has been indicated, this type is in particular need of drainage and, in fact, it cannot be used for the growth of general farm crops until it is thoroly drained. When this is accomplished, satisfactory crop yields may be secured without further treatment. Small applications of farm manure would be of value on newly reclaimed areas in order to stimulate the production of available plant food. The soil is not acid in reaction in all instances, but quite generally becomes so as soon as drainage is established, and, when this occurs, lime will become necessary. The phosphorus supply does not seem to be particularly low, but phosphorus fertilizers will be needed in the future, and may be of value in some instances at the present time.

LOESS SOILS

There are four loess types in the county, which are classed in the Tama, Muscatine, Clinton and Knox series. Almost three-fourths of the total area of the county, 67.7 percent, is covered by these types.

TAMA SILT LOAM (120)

The Tama silt loam is by far the most important soil type in the county, covering 59.4 percent of the total area. It occurs in extensive areas over the uplands in all parts of the county, except along the western boundary where the uplands are covered with Carrington loam.

The surface soil of this type is a dark brown, moderately heavy silt loam, 10 to 12 inches in depth. It grades thru a layer of brown heavy silt loam, about four inches thick, into a brownish-yellow silty clay loam, the color becoming lighter at the lower depths. The color of the subsoil is usually uniform, altho occasionally there is some mottling with light gray and some streaks of rusty iron stains. The depth of the surface soil is somewhat variable. In the flatter areas it is 15 to 18 inches deep, while on the more rolling portions and along gullies it is only 6 to 8 inches in depth, and occasionally the brownish-yellow subsoil is exposed. Narrow strips of colluvial material along some of the intermittent drainageways are included within this type. Where

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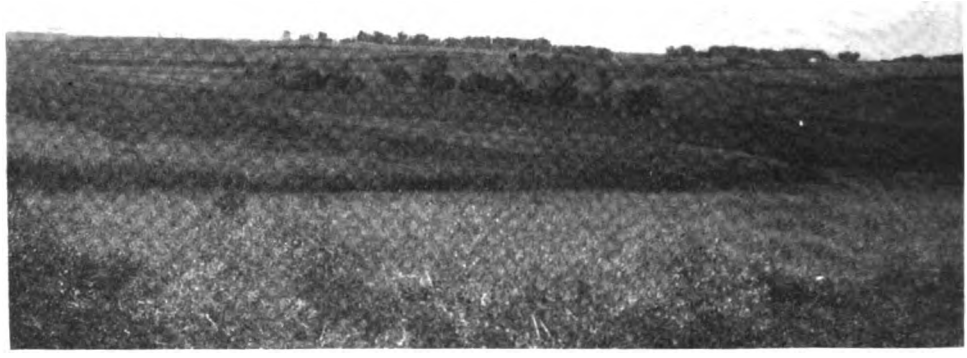

Fig. 10. Typical Tama silt loam topography in Marshall county.

it joins the Clinton silt loam, the surface soil is somewhat lighter in color and the subsoil has some characteristics similar to those of the Clinton. It is difficult to draw a sharp boundary line between these two types.

In topography the Tama silt loam is generally rolling to steeply rolling. Only in the northeastern part of the area does the type become more level. Even here it is usually gently rolling. The soil is well drained and tiling is not necessary. Some washing occurs where the slopes are steep, but there is no extensive action of erosion.

About 95 percent of the type is now under cultivation. At least one-half of this is devoted to corn, the remainder being utilized for growing oats, clover and timothy and some wheat. Corn gives average yields of 45 to 60 bushels per acre and, under favorable conditions, much larger yields than this may be secured. Oats yield at the rate of 35 to 50 bushels per acre. Clover and timothy are the principal hay crops and average yields of 1½ to 2½ tons per acre are secured. Wheat is grown to some extent. Millet, sorghum, barley and rye are also produced on small areas. Alfalfa is grown in a few instances and will undoubtedly prove a profitable crop when more is learned regarding its needs and the conditions under which it will prove successful.

The Tama silt loam is a rather fertile soil and crop yields are generally very satisfactory. It is slightly acid in reaction, however, and should be tested for acidity and lime applied as necessary, if satisfactory crops of legumes are to be secured. Applications of farm manure would be of use in many instances and applications of phosphorus fertilizers might prove of value. The results from the field experiments and greenhouse tests given earlier in this report show very distinctly the value of lime and manure when applied to this soil, and also indicate possibilities of value from the use of phosphorus fertilizers. Tests on individual farms with the use of these latter materials are very desirable and in this way it should be possible to select the particular phosphorus fertilizer which should be used.

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MUSCATINE SILT LOAM (30)

The Muscatine silt loam is the second largest loess soil in the county, covering, however, only a comparatively small area, 4.9 percent of the total. It occurs in rather extensive areas in the north central portion of the county and is also found in a considerable number of smaller areas in the southern part of the county. The most extensive individual area is north of Albion, extending for a distance of over four miles. It is found in association with the Tama silt loam of the upland, occupying the high, slightly undulating to flat areas of the upland.

It occurs in two distinct phases in the county. The more extensive, which is somewhat similar to the Grundy series, is found north of the Iowa river. Here it is a black heavy silt loam, grading at about 12 inches into a black silty clay loam. This in turn passes into a light gray silty clay mottled with yellow and yellowish-brown. This change usually occurs at about 20 inches. Below 40 inches the subsoil becomes lighter in texture and light gray in color. The entire subsoil is granular in structure and very compact. When dry, it is hard and when wet it is inclined to be plastic. South and west of the Iowa river the areas of this soil are more typical of the Muscatine series. Here the soil is a black smooth silt loam, 15 inches in depth, with a heavy black silt loam subsurface, 15 to 24 inches in depth. Below this the subsoil is a gray silty clay mottled with yellow and brownish-yellow.

In topography the Muscatine silt loam is slightly undulating to level and in wet seasons drainage is not entirely satisfactory. Under normal conditions the type is fairly well drained.

Practically all of the soil is under cultivation and the crops grown are very much the same as on the Tama silt loam. Corn is the most important crop, with oats second, and clover and timothy and a few other crops are of minor importance. The yields of all these crops are very much the same as on the surrounding areas of the Tama silt loam.

The soil is acid in reaction and in need of lime. It will respond to applications of farm manure in much the same way that the Tama silt loam responds. Phosphorus fertilizers will probably prove of value in many instances. With these treatments no difficulty should be experienced in securing satisfactory crop yields and keeping the soil highly productive. It should be emphasized that in some instances tile might be installed with value where the drainage is not quite adequate.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type in the county, covering 2.9 percent of the total area. It occurs chiefly south of Marshalltown along Temple creek and in the southwestern part of the county in isolated areas along the bluffs of the Iowa river. The largest individual continuous area is found northwest of Marshalltown, separating the Tama upland from the bottoms along the Iowa river. South of Marshalltown the areas border Temple creek and generally separate the Tama upland from the Wabash bottoms. Frequently, however, areas of Shelby are found between the Clinton and the bottoms. In the southwestern corner of the county the Clinton is associated with the Lindley loam and is separated from the bottoms by areas of this type.

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The surface soil of the Clinton silt loam is a light brown to brown, friable, smooth, silt loam, 6 to 8 inches in depth and underlaid by a brownish silty clay. The subsoil has a granular structure and is very compact, being hard when dry and plastic when wet. Light gray mottlings and yellowish-brown or reddish iron stains are frequently found in the lower sections of the subsoil.

In topography the soil is rolling to rough. The valleys are V-shaped, with steep slopes, and the type is subject to extensive erosion. Drainage is well established.

Practically all of the type was originally forested, chiefly with bur oak, white oak, red oak, hickory, butternut, red elm, dogwood, sumac, prickly ash and hazel brush. Probably 20 percent of the type is still in forest, but larger areas are gradually being brought under cultivation. Where the topography is favorable, corn and small grain crops are grown successfully. On the lower slopes, corn yields from 20 to 40 bushels per acre and oats give satisfactory yields. On the steeper areas neither of these crops proves very successful. Clover and timothy are quite generally grown and utilized for hay.

This soil is acid in reaction and in need of lime. It is low in organic matter and will respond to applications of farm manure. In fact, the use of this material is quite essential for the satisfactory production of corn and small grains on most areas. If farm manure is not available, leguminous crops should be utilized as green manures and every effort should be made to build up the supply of organic matter in the soil. The phosphorus content is not high and applications of phosphorus fertilizers might prove profitable at the present time. They will certainly be needed in the future. On the steeper areas erosion is extensive and prevention or control of this destructive action is very necessary. Probably in some cases it would be more desirable to utilize these steeper areas for pasture and thus prevent the washing away of the surface soil, which is apt to occur rapidly when soils are cultivated.

KNOX LOAMY FINE SAND (141)

This is a very minor soil type in the county, covering only 0.5 percent of the total area. It occurs in several small areas north and west of Marshalltown, north of Quarry and northwest from Albion, and is found along the edge of the uplands adjoining the first bottoms of the Iowa river. It occurs in lower areas than the Clinton silt loam.

The surface soil of the Knox loamy fine sand is a brown loamy fine sand, 6 to 8 inches in depth. The soil passes gradually into a loose, brownish-yellow fine sand, which at 20 inches changes in color to yellow or grayish-yellow. In topography the soil is undulating to hummocky, a condition which has been produced by wind action. Drainage is thoro to excessive, and crops are subject to injury by drouth.

Originally this soil was covered with bur oak, but about 60 percent is now under cultivation and is devoted to truck and cereal crops. Watermelons, cantaloupes and potatoes are grown very successfully. Corn and oats are grown to some extent, but give rather low yields, ranging in the case of corn from 15 to 20 bushels per acre, and for oats, from 15 to 25 bushels per acre. This soil is particularly in need of organic matter if it is to be made satis-

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Fig. 11. The undulating topography of the Knox loamy fine sand in Marshall county has been produced by the action of the wind.

factorily productive. It is extremely low in both organic matter and nitrogen and likewise in phosphorus. Applications of farm manure are very desirable and leguminous crops as green manures would undoubtedly prove of value. The soil is acid and in need of lime. Phosphorus fertilizers could certainly be used with profit where general farm crops are grown. For the production of truck crops, other commercial fertilizing materials might also be used to advantage in certain cases.

TERRACE SOILS

There are three terrace types in the county, classed in the Waukesha, Buckner and Bremer series. They are minor in area, together covering only 2.9 percent of the total area of the county.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the largest terrace type, covering 1.4 percent of the total area of the county. It occurs in isolated areas along the Iowa river and along some of the smaller streams of the county. The largest areas are found north and west of Marshalltown, and small areas occur along Timber creek, Burnett creek, Asher creek, Mud creek and Linn creek.

The surface soil of the Waukesha silt loam is a dark brown, smooth, friable silt loam, about 18 inches in depth. This grades thru a brown heavy silt loam into a brownish-yellow silt loam subsoil, slightly heavier and more compact than the surface soil. The subsoil becomes lighter in color with depth, being yellowish in the lower part, and it has an open, friable structure. In topography the soil is gently undulating and drainage is usually adequate. It lies 10 to 20 feet above the present flood plains, and hence is not subject to overflow.

Nearly all of this type is under cultivation, general farm crops being grown. Corn yields 50 to 55 bushels per acre, oats 40 to 50 bushels and clover and timothy 1½ to 2½ tons per acre.

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The Waukesha silt loam is a rather productive soil, but it will respond to certain fertilizer treatments. It is acid and in need of lime. It is not particularly high in organic matter, and will respond to applications of farm manure. It is not high in phosphorus and applications of phosphorus fertilizers would probably prove of value.

BUCKNER LOAM (38)

The Buckner loam is a minor soil type in the county, covering 1.3 percent of the total area. It occurs in small areas along the Iowa river and along Minerva creek, the larger areas being developed east and north of Clemons.

The surface soil of this type is a dark brown loam, 15 to 18 inches in depth. The subsoil is a yellowish-brown light textured loam to sandy loam. The surface soil varies somewhat in texture from a silty loam to a light textured loam, and some areas of sandy loam are included with the type. The subsoil contains a small amount of coarse sand and gravel and is rather open in texture. It is usually underlaid by fine gravel and sand beds at depths of 4 to 6 feet.

In topography the soil is flat and it contains low ridges, knobs, shallow depressions, channels and a few streams. Drainage is adequate to excessive, and in periods of drouth, crops are apt to suffer.

Practically all of the type is under cultivation. Corn is the leading crop and yields 35 to 45 bushels per acre. Oats give yields ranging from 30 to 40 bushels per acre, and clover and timothy yield 1½ to 2 tons of hay per acre. Potatoes grow well on this type.

This soil is acid in reaction and in need of lime. It is in need of organic matter to increase its water-holding power and prevent injury to crops during periods of drouth. Liberal applications of farm manure would prove of value and leguminous green manure crops should also be used in many cases. Phosphorus fertilizers would probably prove of considerable value on this soil.

BREMER SILTY CLAY LOAM (43)

This is a minor soil type in the county, covering only 0.2 percent of the total area. It occurs in three small areas, two along the Iowa river and one along Minerva creek, the largest area being found west of Minerva Junction.

The surface soil of this type is a black heavy silty clay loam, 18 to 20 inches in depth, grading into a dark slate colored plastic silty clay, faintly mottled with yellowish-brown. At 26 inches, the color changes to a yellowish-gray or bluish-gray mottled with yellowish-brown. In some places, below 8 inches, there is a subsurface layer of black silty clay. During periods of dry weather the soil is apt to crack. The subsoil is hard when dry and plastic and impervious when wet. In topography the type is flat to depressed and drainage is poor.

The soil is largely devoted to corn, yields of this crop averaging 50 bushels per acre. Wheat also does well, giving yields ranging from 20 to 30 bushels per acre. This soil is chiefly in need of drainage in order to make it more productive and, when tile is installed, satisfactory crop yields may be secured without additional treatment. Applications of farm manure would, however, undoubtedly be of value. Phosphorus fertilizers will be needed in the future.

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SWAMP AND BOTTOMLAND SOILS

There are four swamp and bottomland soils in the county, three types which are classed in the Wabash series, and an area of muck. Together they cover 9.6 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland type of the county, covering 7.0 percent of the total area. It occupies the first bottoms along the Iowa river, Minerva creek, Asher creek, Linn creek and Timber creek. It is also found along many of the smaller streams.

The surface soil of the Wabash silt loam is a heavy, smooth, nearly black silt loam, extending to a depth of about 20 inches. This is underlaid by a slightly heavier and more compact silt loam, slightly lighter in color. Frequently there is a little difference in the color or texture of the soils to a depth of 3 feet, and in places the lower subsoil is a dark colored, compact silty clay loam. Occasionally some sand has been mixed with the soil and pockets of sand are frequently found.

In topography the soil is generally flat and the drainage is frequently poor. Clearing and straightening the channels of streams has improved the drainage condition very materially. The type is subject to overflow.

This soil was originally forested with white elm, white ash, willow, cottonwood, box elder and walnut. In some areas the original tree growth still remains, while in others there is a luxuriant growth of marsh grasses. About 75 percent of the soil is devoted to the production of general farm crops. Corn is the chief crop grown and average yields of 50 to 60 bushels per acre are secured. Oats do well, yielding from 30 to 40 bushels per acre. A large part of the type is in hay and pasture.

This soil is very productive under favorable seasonal conditions, and is chiefly in need of adequate drainage and protection from overflow. Small amounts of farm manure would be of value, altho the soil is generally rich in organic matter. Applications of lime would be of value in some instances where the soil is acid, and phosphorus fertilizers will be needed in the future.

WABASH LOAM (49)

This is a minor soil type in the county, covering 1.4 percent of the total area. It occurs in small, narrow areas along the Iowa river and Minerva creek.

The surface soil is a dark grayish-brown to almost black loam to silty loam, 10 to 12 inches in depth, passing into a black loam subsoil which extends to a depth of 3 feet. Both soil and subsoil are friable and open. Occasionally streaks of gray sand are found thru the soil section, and some sand may occur on the surface. In topography the soil is flat, but drainage is quite adequate. The land is overflowed annually.

Along the larger streams the Wabash loam is forested and most of it is in pasture. In some areas the native grasses are cut for hay, yields ranging from 1 to 2½ tons per acre. About 10 percent of the type is devoted to the production of corn, average yields of 40 to 50 bushels per acre being secured. This soil is chiefly in need of protection from overflow in order to produce satisfactory crops. It would respond to applications of farm manure and probably also to phosphorus fertilizers.

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WABASH SILTY CLAY LOAM (48)

This is a minor type in the county, covering 1.1 percent of the total area. It occurs along the first bottoms of the Iowa river and is found in numerous small areas. The largest areas are south of Marshalltown and northwest of Marshalltown.

The surface soil of this type is a black, crumbly, silty clay loam, 6 to 8 inches in depth, grading below this point into a black, sticky clay. From 24 to 36 inches, it changes to a dark slate color, slightly mottled with yellowish-brown. When dry, the soil is hard and compact and when wet, plastic and impervious. In topography the type is flat and slightly depressed. The drainage is very poor. It is subject to annual overflow.

Most of the type is now under cultivation and is largely devoted to corn, oats and hay. Corn yields 50 to 55 bushels per acre, oats 30 to 40 bushels per acre and hay 1 to 2 tons per acre. In wet seasons cultivated crops fail because of frequent overflow, but under normal conditions yields are quite satisfactory.

This type is chiefly in need of drainage in order to produce satisfactory crops. Protection from overflow is also needed. It is acid and in need of lime. Small applications of farm manure would probably be of value and phosphorus fertilizers will be needed in the near future.

MUCK (21a)

There is a very small area of muck in Marshall county, covering 64 acres or less than 0.1 percent of the total area of the county. It is developed in very small areas in the Carrington loam and is found in depressed, poorly drained spots.

Muck is largely made up of partly decomposed organic matter, and this organic material ranges from 24 inches to about 4 feet in depth. It rests on a subsoil of black clay, which changes to a lighter color at lower depths. Marsh grasses grow naturally in these areas and most of the type is used for pasture.

Muck is chiefly in need of drainage in order to be made productive, altho it is apt to be low in plant food constituents and, after being adequately drained, would probably respond to applications of phosphorus fertilizers. These areas of muck in Marshall county are so small that there is no need of considering their adaptation to special crops. They should be drained and brought under cultivation for growing general farm crops, such as are used on the surrounding uplands. Little difficulty is experienced in making these areas of muck satisfactorily productive if they are thoroly drained.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

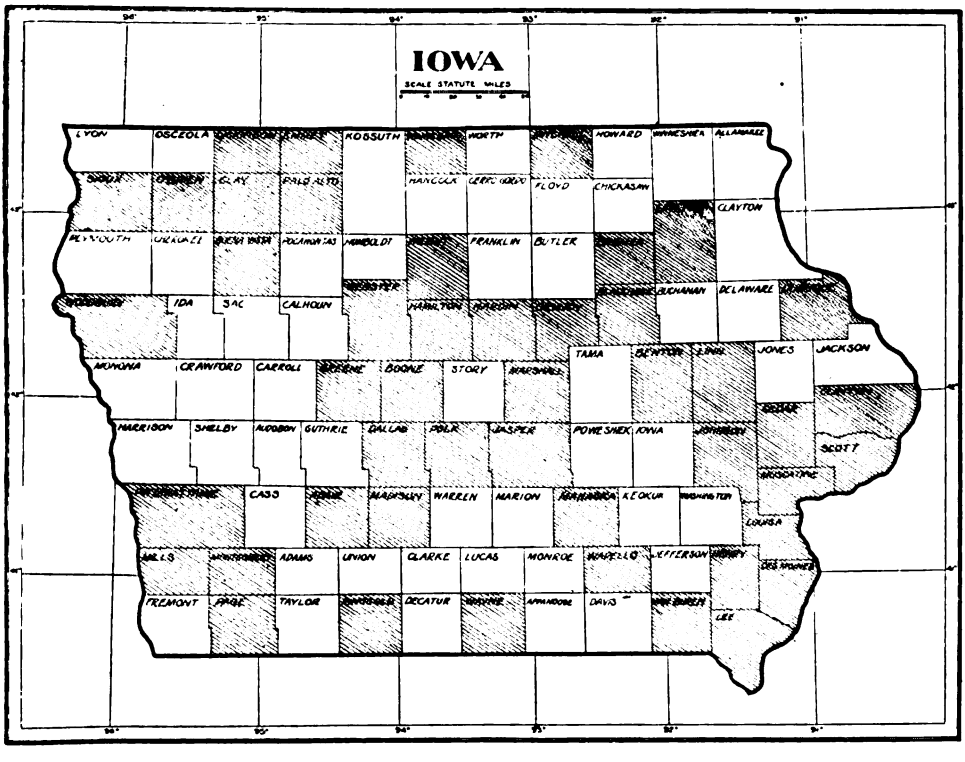

Fig. 12. Map of Iowa showing the counties surveyed.

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The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accummulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavail-*

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

able. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phos-

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phorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still

*Bulletin 150, Iowa Agricultural Experiment Station.

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present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

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But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less

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distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 13.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

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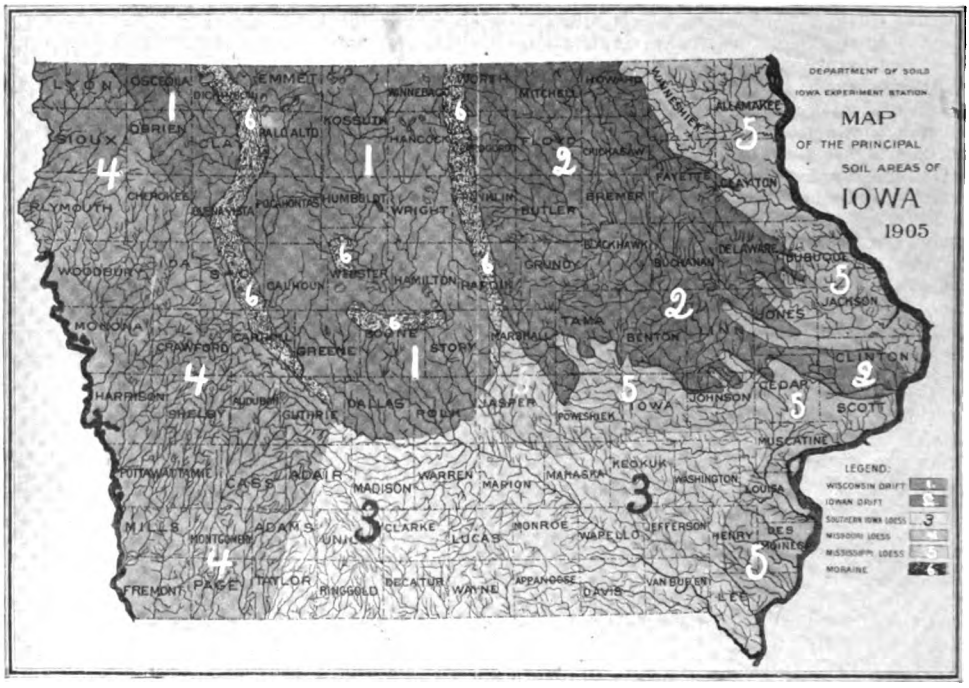

Fig. 13. Map showing the principal soil areas in Iowa

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.

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2. The topography or lay of the land.

3. The structure or depth and character of the surface, subsurface and subsoil.

4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.

5. The texture or porosity, granulation, friability, plasticity, etc.

6. The color of the strata.

7. The natural drainage.

8. The agricultural value based upon its natural productiveness.

9. Native vegetation.

10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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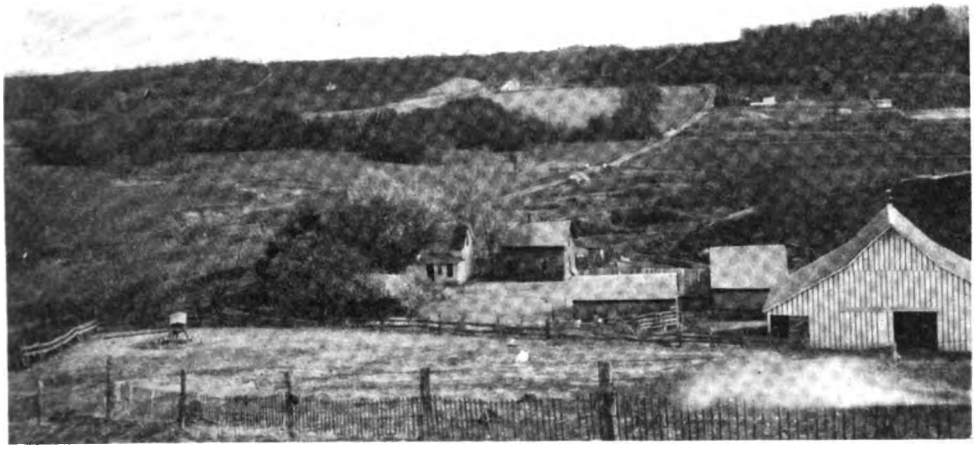
June, 1922 Soil Survey Report No. 26

SOIL SURVEY OF IOWA

Report No. 26—MADISON COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton and L. W. Forman



Typical valley scene in Madison county. Wabash loam is the soil in the bottom, and Lindley loam on the slopes.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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MADISON COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of T. H. Benton and L. W. Forman.

Madison county is located in south central Iowa in the third tier of counties north of Missouri and the fourth tier east of the Missouri river. It is entirely within the southern Iowa loess area and hence the soils of the county are mainly loessial in origin. There is, however, a considerable acreage on which drift soils are mapped, these soils being derived from the glacial material of the Kansan drift. These drift soil areas are found where the covering of loess has been removed by erosion.

The total area of Madison county is 563 square miles or 360,320 acres. Of this area 331,141 acres or 91.9 percent is in farm land. The total number of farms is 2,197 and the average size of the farms is 151 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land in the county:

Acreage in general farm crops	160,454
Acreage in pasture	132,960
Acreage in farm buildings, feedlots and public highways	15,927
Acreage in waste land	3,563
Acreage in crops not otherwise listed	560

The agriculture of Madison county at present is mainly a combination of grain and livestock farming. Practically all of the corn grown (the principal crop) is utilized for the feeding and fattening of hogs and beef cattle. Dairying is carried on to a small extent on some farms in conjunction with the raising of other stock. Much of the oats grown is sold to outside markets and practically all of the wheat produced is shipped out of the county. There is some income from the sale of other crops which are grown to a minor extent. In general the farm income of the county is derived from the sale of livestock and some of the grain crops and it might be considered therefore that the system of agriculture is really a general farming system. The livestock industry, however, is increasing in significance and dairying is also becoming more important.

The area in waste land in the county is rather large, but this land may be reclaimed thru proper methods of soil treatment. It is not possible to make general recommendations for the treatment of such land, inasmuch as the causes of infertility are various. Special treatments which are desirable under individual soil conditions will be suggested in a later section of this report. In special cases, for more or less abnormal conditions, advice regarding treatment may be obtained from the Soils Section of the Iowa Agricultural Experiment Station.

MADISON COUNTY CROPS

The general farm crops grown in Madison county in the order of their importance are: corn, hay, oats, wheat, barley, potatoes, alfalfa and rye. The average yields and value of these crops grown in the county are given in table I.

*See Soil Survey Report of Madison County, Iowa, by T. H. Benton of the Iowa Agricultural Experiment Station and Hugh B. Woodroffe of the U. S. Department of Agriculture.

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TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN MADISON COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	88,500	26.7	49.0	4,336,000	$0.47	$2,037,920
Oats	27,600	8.3	46.0	1,269,600	0.36	457,056
Spring wheat	1,440	0.4	11.0	15,800	1.35	21,330
Winter wheat	16,800	5.0	19.0	319,200	1.41	450,072
Barley	3,000	0.9	31.0	93,000	0.63	58,590
Rye	610	0.1	17.0	10,370	1.17	12,132
Potatoes	264	0.07	113.0	29,832	1.22	36,395
Tame hay	20,790	6.2	1.4	29,100	16.24	472,584
Wild hay	1,070	0.3	1.3	1,391	12.69	17,651
Alfalfa	480	0.1	2.4	1,152	19.23	22,152
Pasture	132,960	40.1	....	.....	....	.....

Corn is the most important crop in the county, both in acreage and in value. It is grown in all parts of the area and on practically all soil types. Slightly over one-fourth of the total area of farm land in the county is used for this crop. Average yields of 49 bushels per acre were secured in 1920. The most extensively grown variety is Reid's Yellow Dent. Other popular varieties are Boone County White, Pride of the North, Leaming and Little Calico. Practically all of the corn produced is fed on the farms. A large part of it is cut, shocked and fed whole or shredded or used for ensilage. Hogging down is practiced quite extensively and rape or cowpeas are often sown in the corn after the last cultivation.

Hay is the second crop in value in the county, occupying, however, a somewhat smaller acreage than oats. The chief hay crops of the county are timothy and clover mixed and timothy alone. Average yields of tame hay amount to 1.4 tons per acre. Some clover is grown alone and both clover and timothy are sometimes grown for feed. There is only a relatively small acreage in wild hay, chiefly in the bottomlands along the North river.

Oats is the second crop in acreage and the third in value. Average yields amounted to 46 bushels per acre in 1920. The principal varieties grown are Green Russian and Iowa 103. Some Kherson and Early Champion are also grown. A part of the oats produced is used as feed for the work stock. A considerable quantity is sold, chiefly to the markets in Chicago and Kansas City.

Wheat is the fourth crop in acreage and value, being grown on 5.4 percent of the total farm land of the county. Average yields of 19 bushels per acre are secured for the winter varieties and 11 bushels per acre for the spring varieties. Winter wheat is grown most extensively and only a relatively small acreage is devoted to spring wheat. This crop has only recently been grown to any extent in Madison county, but during the past few years, it has come to be of considerable importance. Turkey is the principal variety grown, and occasionally Iowa 404 and Fultz are grown. Bluestem and Marquis are the principal spring varieties. Practically all of the wheat produced in the county is shipped to outside markets.

Barley is grown to a small extent in the county, with average yields of 31 bushels per acre. Potatoes are grown on practically all farms, with average yields of 113 bushels per acre. Early Rose, Early Ohio, Snowflake, and Rural

*Iowa Yearbook of Agriculture for 1920.

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New Yorker are the principal varieties. The potatoes grown are all used to supply the home demand and considerable quantities must be shipped in each year to make up the deficit.

Alfalfa is being grown on a small acreage in the county with average yields of 2.4 tons per acre. This crop can undoubtedly be grown very successfully in the county when the soil is properly prepared and all precautions are taken in securing good seed and seeding. Lime is needed and inoculation should be practiced if the crop is to prove successful. Where care has been taken, success has followed the growing of this crop. It will undoubtedly be utilized more extensively in the county as more is learned regarding its value.

Rye is grown on a small area in the county and it is comparatively minor in importance. Buckwheat, kafir, sweet corn and popcorn are all grown to a minor extent. There are also small patches of millet and sorghum. Sudan grass is being grown in a small way with success, chiefly in the northern part of the county. Bluegrass is utilized mainly for pastures. In addition to alfalfa, other legumes grown on small areas include soybeans, vetch, red clover, peas, beans and peanuts.

Trucking is practiced to a very minor extent, chiefly to supply the local markets. Fruit growing is not of much significance in the county. There are a few commercial apple orchards but they are small. The principal varieties grown are the Duchess, Red June, Yellow Transparent, Ben Davis, Jonathan, Grimes, Wealthy, Winesap, and Delicious. Many of the farm orchards are being replanted and in general more care is being taken of the trees. Plums, cherries, grapes, strawberries and raspberries are grown in sufficient quantities in the county to supply the local markets.

THE LIVESTOCK INDUSTRY IN MADISON COUNTY

The livestock industries of the county include cattle raising and feeding, hog raising and feeding, sheep raising, and dairying. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the extent of the livestock industry in the county:

Horses, all ages	12,207
Mules, all ages	913
Swine (on farms July 1, 1920)	86,075
Swine (on farms January 1, 1921)	69,246
Cattle (cows and heifers kept for milk)	7,954
Cattle (other cattle not kept for milk)	24,533
Cattle (total all ages January 1, 1921)	32,487
Sheep (all ages on farms)	18,530
Sheep (shipped in for feeding 1920)	3,224
Sheep (total pounds of wool clipped)	106,884
Poultry (total number, all varieties, January 1, 1921)	245,994
Poultry (number of dozen eggs received 1920)	1,046,441

The raising and feeding of cattle is the most important livestock industry in the county. The beef cattle raised are mostly grade Shorthorns and Aberdeen Angus. There are, however, some purebred herds, principally Angus, Hereford and Shorthorn. From 115 to 120 carloads of feeders are shipped in annually from St. Paul, Omaha and Kansas City. On nearly every farm a few head are fattened and sold, while in many cases several carloads are shipped in and fed. They are marketed in December and January, being shipped to Chicago, St. Joseph, Kansas City and Ottumwa.

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Hog raising is almost as important as cattle raising in the county. The breeds are mainly Poland-China and Duroc-Jersey. There are also some Hampshire and Chester White. Most of the hogs shipped from the county are sent to the larger markets at Chicago, St. Joseph and Kansas City. Hogs are butchered on every farm to supply meat for home consumption.

Sheep raising is a minor industry, but it is gradually increasing in importance. The rougher lands in the Lindley and Shelby series are well adapted to sheep raising, as excellent bluegrass pastures are maintained. Shropshire, Merino and Delaine are the principal breeds. A few carloads of grade westerners are shipped in and fed, principally in the southern part of the county.

Dairying is developed to a small extent in the county, but in general enough cows are maintained on every farm to supply the home demand for dairy products. Near the larger towns there are a few fair sized dairy herds. Holsteins and Jerseys are the favorites. There are no creameries in the county and the dairy products are nearly all utilized locally, only a small amount of cream being shipped. On the general farms, dairy cattle are mainly grade Shorthorns.

Some horses are raised, enough to maintain a small number on all farms. There are a few mules in the county and in some of the extremely rough areas there are a few herds of goats.

Poultry raising is proving a very important industry in the county and the egg production in 1920 was considerable.

The value of land in Madison county is somewhat variable, depending upon the location with reference to towns and to railroad facilities, the improvements on the farms, topography, soil type and general soil conditions. The selling price ranges from $70 to $325 per acre. Small areas of the rougher land in the timbered sections are valued at about $40 per acre. The average price of the better farm land would range from $250 to $325. In some instances even larger prices than this have been secured and it is generally recognized that the more level areas of upland in the county are very valuable for general farming purposes.

THE NEEDS OF MADISON COUNTY SOILS

The yields of general farm crops in Madison county are quite satisfactory, but they may be increased in many instances thru the adoption of proper methods of soil treatment. The particular treatment which should be followed in any case will depend upon the individual soil conditions and particularly the topographic condition. In general, it may be said that crop production may be increased thru proper drainage, liming, manuring and fertilization and protection of the soil from erosion.

In some instances the soils are improperly drained. When this is true the installation of tile is the first treatment needed to bring about satisfactory crop growth. No other treatment of the soil will be of value if it is too wet and even tho the expense of tiling is considerable, tile should be installed whenever it is necessary if satisfactory crop yields are to be secured.

Madison county soils are practically all acid and lime must be applied if the best growth of general farm crops is to be secured, particularly with legumes. All of the soils of the county should be tested for lime requirement.

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Many of the soils in the county are rather poorly supplied with organic matter and in all cases applications of farm manure have been found to be of value. If farm manure is not available in sufficient amounts, it may be desirable in many cases to turn under a legume crop as a green manure in order to keep up the organic matter content of the soil. Such crops also aid in keeping up the nitrogen supply and in many of the types in the county it is very important that the nitrogen content be increased and in all cases care should be taken to keep up the supply. Leguminous crops as green manures are the cheapest and most satisfactory source of nitrogen.

The phosphorus content of the soils of the county is low and phosphorus fertilizers will need to be used at some time in the near future if this element is not to become deficient. It seems quite possible that these materials may be used with profit in some cases at the present time. Until the field experiments now under way in the county are more complete, the testing of phosphorus fertilizers on small areas on individual farms is the only definite recommendation which can be made along this line. Complete commercial fertilizers cannot be recommended for general use in the county at the present time. They may be tested, however, on individual farms and their actual value determined.

Erosion has occurred to a large extent in some parts of Madison county and there is some formation of gullies and much sheet erosion. It is very important that some method of treatment, as suggested later, be followed to control the destructive action of erosion.

THE GEOLOGY OF MADISON COUNTY

The early geological history of Madison county need not be considered at length, as it has had very little effect upon the present soil conditions. The original bedrock material in the county has been buried deeply by the later deposits of glacial drift and loess and hence has very little influence on the soil characteristics. This bedrock material consists mainly of limestones, shales and sandstones; there are two residual soil types mapped in the county which are derived in large part from the bedrock limestone, the Sogn and Hagerstown series. They are not important, agriculturally, in the county, occurring only in small areas. These soils are mapped on the sides of steep slopes where the coverings of loess and drift have been washed away to a large extent and the limestone material has been exposed.

At least once during the glacial age a great glacier crossed the county and upon its retreat left behind a vast deposit of drift or till. This material, which is known as Kansan drift, is quite variable in depth, extending to many feet in some areas. Apparently the topographic features of the county preceding the invasion by the glacier were modified to some extent and the glacial material covered the older topographic features, completely filling the depressions or valleys and also covering the higher land. The depth of the deposit, however, varies somewhat, depending upon the earlier topographic features. The drift material is naturally a bluish-gray mixture of clay, silt, sand and gravel containing numerous boulders. Where exposed to the weather, the drift has been oxidized to a yellowish or reddish-brown and this weathered layer may vary

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from a few inches to three or four feet in depth. The subsoil usually consists of a silty clay to clay, very tenacious and plastic. Fairly large mixtures of coarse sand, gravel and boulders occur thruout the surface soil and subsoil. Lime has been leached away from the soil quite completely. Calcareous material is found only in the lower sections at depths of from five to seven feet. The surface soil has been modified in many cases thru mixtures with organic matter and it has become darker in color. The soils of the Shelby and Lindley series are derived from this Kansan till, having been formed by the washing away of the surface covering of loess.

At some previous geological period, when climatic conditions were very different than at present, a layer of loess was deposited by the wind over the entire surface of the county. In its unweathered condition loess is an even-grained material, composed mainly of silt with some clay. It ranges in color from a light grayish-brown to a yellowish-brown. There has been an accumulation of organic matter in the surface soil and the color has been darkened. Under prairie conditions the greater plant growth and accumulation of residues has led to the formation of the dark colored Grundy and Tama soils, while under wooded conditions the soils of the Clinton series, which are lighter colored, have been developed. The lime has been removed practically completely from all the loess areas and there has been considerable washing of the loess soil. In some instances the covering of loess has been completely removed. This is true where the Shelby soils are mapped. In other cases only a partial removal has occurred and here the soils are in the Lindley series. In much of the remainder of the county the loess covering which remains is quite extensive and where the topography is more nearly level, there has been very little washing away of the surface soil.

There are rather extensive areas of first and second bottomlands in the county and these are made up in large part of the loessial material washed down from the uplands. There is, however, also a considerable mixture with drift material carried down from the higher land along with the loess. Where the soils are above overflow, soil types have developed which are quite distinct in characteristics from the bottomland soils.

PHYSIOGRAPHY AND DRAINAGE

The original topography of the county was that of a rather level loess-covered plain, sloping to the northeast at the rate of about 10 feet per mile. This earlier topography has been greatly modified, however, thru the erosional action of the streams and two distinct types of topography have developed. In the northwestern quarter of the south central part of the county, the surface is gently undulating to level in topography. Here the action of erosion has been less extensive, the valleys of the main streams are V-shaped, deeply cut, the slopes rather steep, the bottomlands narrow and the tributary streams short. In the area east of Clanton creek, from St. Charles south to South river, the topography is similar to that just described. In the area between Middle and Grand rivers in the southwestern part of the county, the topographic features are more extreme. Here the original surface deposits have been very largely carried away by stream action, but the tributaries of the streams have cut back so far into the

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upland that there is very little of the original upland between them which has not been affected by washing.

The eastern part of the county, except the plain east of Clanton creek, has been quite extensively cut by stream action. Broad, flat valleys have developed along the main streams and the smaller streams have cut into the remaining upland areas so that the topography is rolling to hilly or even steep. There are some flat areas on the tops of divides between the streams, but in general the uplands in the county are rolling to rough in topography and are quite thoroly drained thru the intermittent drainageways of small streams leading to the larger rivers.

The natural drainage of the county, with the exception of a few small areas just mentioned, is good. The county drains in general toward the east thru the Clanton river, Middle river and the North river with their tributaries. Badger creek, Jim creek, North Branch, Howerdon and Cedar creek are the chief tributaries of the North river draining the entire northern half of the county.

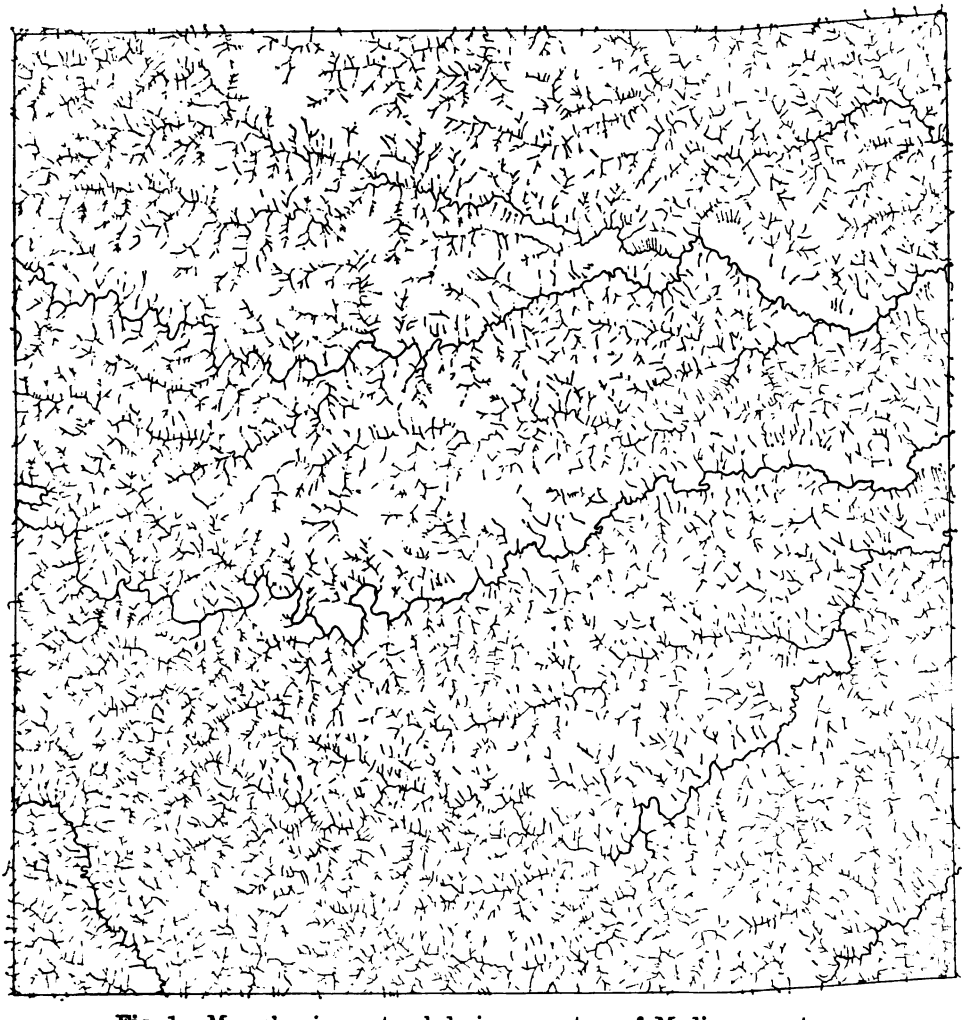

Fig. 1. Map showing natural drainage system of Madison county.

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Middle river has only a few small tributaries, none of them being developed to any extent. This river drains the central portion of the county. Clanton creek with its tributaries, Jones creek, North Fork Clanton creek and South Fork Clanton creek, drains most of the southern part of the county. South river crosses the extreme southeastern corner of the county, draining that area, while Grand river crosses the southwestern corner of the county, draining that portion.

Some of the larger streams have developed channels 100 to 250 feet below the upland plain. The south slopes of the stream channels are generally rough and abrupt, with a growth of forest trees. On the north side of the streams there are more gentle hills and slopes. Terraces occur along all the larger streams and range in width from one-eighth to three-fourths of a mile. They generally lie five to twenty feet above the flood plains and occur in irregular bodies and discontinuous strips. The terraces are most extensively developed along Middle river and Clanton creek. Bottomlands are found along nearly all the streams of the county and much of the material is being continually reworked thru the action of the streams.

In general the drainage system of the county is quite adequate, as will be apparent from an examination of the drainage map. Areas of upland in the northwest and central parts of the county, however, would be benefited by drainage. The areas mapped as Grundy silt loam on the soil map would indicate very largely the location of areas where drainage may be inadequate and where tiling should be practiced. With the exception of this one soil type and of the more level to flat areas where it occurs on the uplands, drainage is only infrequently needed. The installation of tile may be of value, however, in some cases in the county and adequate removal of excessive moisture may readily be secured because of the quite complete drainage system.

THE SOILS OF MADISON COUNTY

The soils of Madison county are grouped into five classes, according to their origin and location: drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils. Drift soils are formed from the materials carried by glaciers and deposited upon the surface of the land when the glacier retreated. They are extremely variable in composition and contain pebbles and frequently boulders. Loess soils are fine, dustlike deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by decreases in the volume of the streams which deposited them or by a deepening of the river channels. Swamp and bottomland soils are those occurring in low, poorly drained areas and they are subject to more or less frequent overflow. Residual soils are produced by the weathering of the underlying rock material and remain in the location where they were formed.

The extent and occurrence of these five groups of soils of Madison county are shown in table II.

Considerably over one-half of the total area of the county, 63.7 percent, is covered by the loess soils. On almost one-quarter of the county's area the

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TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN MADISON COUNTY

Soil group	Acres	Percent of total area of county
Drift soils	87,104	24.2
Loess soils	229,568	63.7
Terrace soils	7,744	2.1
Swamp and bottomland soils	24,896	6.9
Residual soils	11,008	3.1
Total	360,320	....

loess has been removed and the drift soils exposed, 24.2 percent of the county being in drift soils. The terrace types are of minor extent in the county, covering only 2.1 percent of the total area. Swamp and bottomland soils are of considerable importance, together covering 6.9 percent of the county. Residual soils are minor in area and are relatively unimportant agriculturally. Together they cover 3.1 percent of the total area of the county.

There are 15 individual soil types in the county. Two of these are drift soils, three are loessial in origin, four are terrace types, four are bottomland soils and two are residual soil types. These individual soil types are distinguished on the basis of certain characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Tama silt loam is the largest individual soil type in the county, covering half of the total area. The Shelby loam is the second largest type and the largest drift soil, covering 19.9 percent of the county. The Clinton silt loam is the third largest type, and the second largest loess soil, covering 9.3 percent of the total area. The Lindley loam is the second largest drift soil, covering 4.3 percent of the county. The Grundy silt loam, a loess soil, is somewhat smaller in area, covering 4.1 percent of the county. The terrace soils are all minor in area, the Waukesha silt loam, the largest, covering one percent of the

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MADISON COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
79	Shelby loam	71,744	19.9
65	Lindley loam	15,360	4.3
	LOESS SOILS		
120	Tama silt loam	181,184	50.3
80	Clinton silt loam	33,472	9.3
64	Grundy silt loam	14,912	4.1
	TERRACE SOILS		
75	Waukesha silt loam	3,584	1.0
88	Bremer silt loam	2,688	0.7
81	Jackson silt loam	1,152	0.3
42	Calhoun silt loam	320	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	11,840	3.3
62	Wabash fine sandy loam	5,248	1.4
49	Wabash loam	4,608	1.3
48	Wabash silty clay loam	3,200	0.9
	RESIDUAL SOILS		
155	Sogn stony silt loam	10,368	2.9
156	Hagerstown silt loam	640	0.2

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county. The other terrace types are much smaller in area, the smallest, the Calhoun silt loam, covering only 0.1 percent of the county. The swamp and bottomland soils are all small in area, the largest, the Wabash silt loam, covering 3.3 percent of the total area. The other types cover 1.4 percent, 1.3 percent and 0.9 percent, respectively, for the Wabash fine sandy loam, Wabash loam and Wabash silty clay loam. The residual soils are both small in area, the Sogn stony silt loam covering 2.9 percent of the county while the Hagerstown silt loam covers only 0.2 percent of the county.

The loessial upland soils of the county are in general gently undulating to rolling, which is characteristic of the Tama silt loam. The Clinton silt loam is more steeply rolling to rough and in the wooded sections may be quite steep The Grundy silt loam, on the other hand, is more level and rather poorly drained. The Shelby loam and Lindley loam of the drift uplands are both rolling to rough, many of the areas being steep and utilizable only for pasture. The terrace types and swamp and bottomland soils are quite generally level and in the case of the bottomlands, drainage is somewhat inadequate and the types are subject to overflow. The residual soils are rough, the land is not agricultural, and much of it is not even available for use as pasture.

THE FERTILITY IN MADISON COUNTY SOILS

Samples were taken for analyses from each of the soil areas in Madison county except the two residual soils, the Sogn stony silt loam and the Hagerstown silt loam. These latter types were not sampled nor analyzed, owing to their small occurrence and unimportance agriculturally. The more extensive types were sampled in triplicate while only one sample was taken in the case of the minor types. All the samplings were made with the greatest care that the samples should be representative of the particular soil type and that variations due to local conditions or to previous treatment should be eliminated. The samples were drawn at three depths, 0-6 2/3″, 6-2/3—20″ and 20—40″, representing the surface soil, the subsurface soil and the subsoil, respectively.

Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official method, and the Veitch method was followed for the limestone requirement determinations. The figures given in the tables are the averages from the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of 4 or 12 determinations.

THE SURFACE SOILS

The results of the anlyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is extremely variable, ranging from 942 pounds in the Shelby loam up to 2,949 pounds in the Wabash loam. There is no distinct relationship evident between the phosphorus content and the various soil groups, altho it is apparent that the drift soils are somewhat lower in this constituent than the other soil groups. The average of the loess soils seems to be somewhat lower than that of the terrace

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TABLE IV. PLANT FOOD IN MADISON COUNTY, IOWA, SOILS
Pounds per acre of Two Million Pounds of Surface Soil (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	942	4,288	51,640	0	2,802
65	Lindley loam	990	1,050	10,524	32,616	Basic
	LOESS SOILS					
120	Tama silt loam	1,591	5,179	63,600	0	3,203
80	Clinton silt loam	1,017	2,615	30,580	0	2,135
64	Grundy silt loam	1,070	4,456	52,440	0	5,605
	TERRACE SOILS					
75	Waukesha silt loam	1,865	4,806	58,450	Trace	Basic
88	Bremer silt loam	1,865	4,316	57,720	0	3,003
81	Jackson silt loam	1,434	3,838	45,220	0	1,201
42	Calhoun silt loam	1,549	3,334	40,780	0	2,402
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,175	7,202	83,627	Trace	Basic
62	Wabash fine sandy loam	1,495	3,124	40,025	Trace	Basic
49	Wabash loam	2,949	5,912	63,029	1,471	Basic
48	Wabash silty clay loam	1,582	5,520	69,096	Trace	Basic

group and the swamp and bottomland group. It is, however, somewhat greater than the average of the drift soils, but the differences here are not large enough to be very distinct. It might be expected that the bottomland soils would be somewhat richer in phosphorus than the upland types, owing to the fact that there has been less crop production on these types and hence a smaller removal of phosphorus as well as of all other plant food constituents. Similarly the terrace types might be expected to be somewhat richer than the upland soils, but not as high as the bottomland types. These relations seem to be fairly apparent in the case of the soils of this county.

There are, however, some rather wide variations in phosphorus content within the various soil groups, and there is a much more definite relation between the phosphorus supply and the soil series; undoubtedly the soil type bears a very important relation to the phosphorus content.

The Tama silt loam is better supplied with phosphorus than the Clinton and Grundy soils in the loess group. The Waukesha and Bremer soils of the terrace group are richer in phosphorus than the Jackson and Calhoun types. These differences may be traced to the topographic conditions, the accumulation of organic matter, or the way in which the various soils have been handled, but they are all differences which are characteristic of the particular soil types. It is not possible to draw any very extensive conclusions as to the effect of soil texture on phosphorus, as so many of the types in the county are silt loams. Only in the swamp and bottomland group is there any opportunity to make a comparison of the effect of texture within a soil series. Here it would seem that the Wabash fine sandy loam is lower in phosphorus than the heavier textured types. The loam, however, is better supplied than the silty clay loam; in fact, the silt loam is higher than the silty clay loam. This is contrary to the results usually secured, as ordinarily the heavier textured types contain the largest amount of phosphorus. Perhaps the silty clay loam in this county is somewhat abnormal and the phosphorus content has been influenced by some

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unusual factor. It does seem to be evident, however, that fine textured soils, such as sandy loams, may be lower in phosphorus than heavier types like the silt loam and loam.

It is quite apparent from the figures given that the phosphorus content of the soils of the county in general is not very high and in many cases phosphorus fertilizers would probably prove of value at the present time. These materials will undoubtedly be needed in the near future and they must be taken into account in planning systems of permanent fertility for this county. Analyses do not show how much phosphorus is produced in an available form, but if there is a large total supply and the soil conditions are satisfactory, it is usually quite safe to conclude that there will be a sufficiently rapid production of the element in an available form and crops will be well supplied. If the total supply is low, however, it is usually safe to assume that there will not be a sufficient production of available phosphorus to meet the crop demands.

Inasmuch as the phosphorus content of the soils in Madison county is usually rather low, it seems quite probable that in many cases available phosphorus is not being produced as rapidly as it is needed. Whenever this is true, phosphorus fertilizers may be used with profit. Farmers may test the value of applications of phosphorus to their soils and thus determine for their own conditions, whether or not phosphorus fertilizers should be used. If crop yields are increased to a profitable extent on small areas, then the same fertilizer may be used on a larger area with the assurance of profit.

The nitrogen content of the soils of the county is quite variable, ranging from 1,050 pounds in the Lindley loam up to 7,202 pounds in the Wabash silt loam. With the possible exception of the Lindley loam, the soils of the county do not seem to be strikingly deficient in nitrogen, but this element must be considered in planning systems of permanent fertility for the soils of this county. There is no relation apparent between the nitrogen content of the soils and the various soils groups except that as in the case of phosphorus the terrace soils are somewhat better supplied with nitrogen than the upland types, while the bottomland soils are richer than the terrace types. Again this relation might be expected because of the smaller crop growth and less utilization of nitrogen in terrace and bottomland types.

There are some relations evident between the soils of different series even within the same soil group. These differences, as in the case of phosphorus, may be very closely linked up with the soil series or the characteristics which determine a soil series. Thus the Tama silt loam is higher in nitrogen than the Clinton. The Grundy is likewise higher than the Clinton. Both the Tama and the Grundy differ markedly from the Clinton in topography conditions and they have been formed from the original soil material under different conditions. The Clinton was originally a wooded soil while the others were prairie types. The Shelby loam is higher than the Lindley loam in the same group, which is again a difference dependent upon the characteristics of the soil series. The Waukesha and Bremer soils of the terrace group are higher than the Jackson and Calhoun types. The Wabash fine sandy loam is much lower in nitrogen than the other types of the Wabash group. The silt loam is the highest among the Wabash soils. Considering the effects of texture

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which appear only in this group of soils, it is evident that the silt loam is somewhat an abnormal soil and probably contains a much higher amount of nitrogen in relation to the other Wabash types than is usually the case. The silty clay loam seems to be somewhat lower than would be expected, and while it is not possible to draw conclusions regarding the soil textures and the nitrogen content, it would seem that the light textured soils are poorer in nitrogen than the heavier textured types. This difference would undoubtedly be more apparent if other types of the same series had been mapped on the uplands.

As will be noted later, there is a relation between the nitrogen content and color, which means a distinction on the basis of soil series. Apparently none of the soils of the county is extremely low in nitrogen, but the treatments practiced in all these soils must include the addition of some nitrogenous fertilizer if the supply of this element is not to become lacking.

Considerable amounts of nitrogen are returned to the soil in farm manure and this material is a most important fertilizer from the nitrogen standpoint. It may return to the land a considerable portion of the nitrogen removed by crops grown. Crop residues also return to the soil some of the nitrogen removed by crops, but these materials alone are not sufficient on the average farm to permit the nitrogen supply to be kept up. It is necessary in practically all systems of farming to make use of leguminous crops as green manures to increase the nitrogen content of the soil. Wherever farm manure is lacking or is insufficient, green manuring should be practiced and the nitrogen content in the soil built up by utilizing that element as taken from the air. The actual amount of nitrogen added to soils by growing legumes and turning them under will depend upon many factors, such as the character of the crop grown, the thoroness of inoculation and the nitrogen content of the soil. In the case of clover, the nitrogen content of the tops seems to be about equal to that taken from the air and hence the addition of nitrogen to the soil will depend upon the size of the clover crop and whether or not it is all turned under. Leguminous green manure provides the cheapest and best source of nitrogen and the practice of green manuring is of large value in keeping up the supply of nitrogen in soils.

There is a rather distinct relation between the nitrogen and the organic carbon in soils and the content of both these constituents is rather definitely indicated by the color of the soil. If it is black, the organic carbon and nitrogen content is high. If it is light the supply of these constituents is low. The soils of Madison county show a wide variation in organic carbon content, but rather definite relations occur between the organic carbon and the nitrogen in the case of all the soil types. Where the nitrogen is high there is a large amount of organic carbon. Where the nitrogen is low, the organic carbon content is likewise low. Thus the Lindley loam, which is the lowest in nitrogen of all the types, is the lowest also in organic carbon, while the Wabash silt loam, which showed the highest content of nitrogen, gives likewise the largest amount of organic carbon.

The same relations between the soil groups, the soil series and the individual types of this texture in the case of nitrogen, all hold true for the organic carbon. The heavier textured types are in general higher in both these con-

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stituents while the soils of certain series whose characteristics are determined by topography, origin, color and other factors, are higher in organic carbon as well as in nitrogen than some of the other types. In series of different characteristics, the soils under more level topography conditions seem to be higher in these constituents than the more rolling types. The Wabash fine sandy loam is the lowest in organic carbon of any of the Wabash soils, as would be expected. The Wabash loam is somewhat lower than the silt loam, as would also be expected, but the silty clay loam is not as high as the silt loam, which is contrary to the usual results secured in comparing soils of these textures.

The relation between the carbon and nitrogen present in soils gives some evidence of the rate at which plant food is being made available. In practically all cases the relation between these constituents in the soils of Madison county is quite satisfactory. There are a few instances, however, where decomposition is not going on properly and, when this is true, applications of farm manure will be of especial value, because this material increases the rate of decomposition and brings about a greater production of available plant food. It is urged that farm manure be used on all the soils of the county, even on those types where the color is dark and the content of organic matter seems to be rather high. Experiments and farm experience have shown the large profit from the use of this material in liberal amounts.

Only in two of the soil types in the county is there any supply of inorganic carbon and in both of these soils the occurrence is not at all constant. Only occasionally will lime be found to as large an extent in the surface soil as the analyses show. The occurrence of lime or inorganic carbon in the Wabash loam is not characteristic and other samples of this type would undoubtedly be acid. In general, the upland soils of the county seem to be lacking in inorganic carbon and in need of lime. Most of the terrace types are likewise in need of lime. The bottomland soils, while not supplied with any large amount of lime, are apparently basic in reaction. Very soon, however, these soils will need lime, as there is a constant removal of material thru leaching and the inorganic carbon will decrease rapidly.

No large lime requirement is shown for any of the soil types, but as crop production continues, the need of lime will become more and more evident. Soils vary widely in lime requirement and every soil should be tested before lime is applied.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

Taking into account the plant food content of the lower soil layers, the needs of the soils of the county would not be shown to be any different than indicated by the analyses of the surface soils. Unless there is a large amount of plant food in the lower depths, the composition of the surface soil determines quite definitely the fertilizer requirements. The lower soil layers in Madison county do not contain any larger amounts of plant food than the surface soils and hence the conclusions reached in the analyses of the surface soils are confirmed by the results secured from the analyses of the lower soils layers. It will not

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TABLE V. PLANT FOOD IN MADISON COUNTY, IOWA, SOILS
Pounds per acre of Four Million Pounds of Subsurface Soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	2,034	4,036	48,240	0	8,808
65	Lindley loam	1,320	3,504	28,920	0	8,808
	LOESS SOILS					
120	Tama silt loam	2,536	7,078	85,240	0	7,740
80	Clinton silt loam	1,867	3,588	38,240	0	5,472
64	Grundy silt loam	1,324	4,484	49,840	0	5,605
	TERRACE SOILS					
75	Waukesha silt loam	3,212	7,312	93,622	Trace	Basic
88	Bremer silt loam	2,640	5,492	77,620	0	8,007
81	Jackson silt loam	2,155	3,308	29,480	0	4,004
42	Calhoun silt loam	3,044	2,692	24,400	0	6,406
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,990	6,612	84,332	Trace	Basic
62	Wabash fine sandy loam	2,963	3,364	46,854	Trace	Basic
49	Wabash loam	4,175	9,080	105,457	1,263	Basic
48	Wabash silty clay loam	2,141	5,436	81,541	Trace	Basic

be necessary, therefore, to discuss the analyses of the subsurface soils and subsoils in detail.

Phosphorus fertilizers will certainly be needed on the soils of Madison county in the future, as the supply of this constituent is low. There are indications that these materials may prove of value in some instances at the present time. The supply of organic matter and nitrogen must be maintained. Farm manure, crop residues and leguminous green manures should be utilized on all the soils of the county. Most of the soils in the county are acid and in need of lime and even in those cases where acidity is not shown at present, there is no large content of inorganic carbon and the soils will become acid in the near future. Even in the few instances where there is considerable lime in the subsoil, there will be no effect upon the needs of the surface soils, as lime rarely

TABLE VI. PLANT FOOD IN MADISON COUNTY, IOWA, SOILS
Pounds per acre of Six Million Pounds of Subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	1,717	3,528	44,400	0	19,217
65	Lindley loam	2,222	2,604	30,660	0	19,217
	LOESS SOILS					
120	Tama silt loam	3,576	9,542	112,120	0	11,611
80	Clinton silt loam	2,774	4,132	35,633	0	11,210
64	Grundy silt loam	2,101	4,332	42,762	1,038	Basic
	TERRACE SOILS					
75	Waukesha silt loam	4,000	6,894	90,224	1,096	Basic
88	Bremer silt loam	4,202	4,623	64,710	0	4,805
81	Jackson silt loam	3,414	4,626	35,340	0	6,006
42	Calhoun silt loam	2,748	3,318	27,780	0	12,012
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,636	5,382	76,560	0	13,213
62	Wabash fine sandy loam	3,939	4,626	57,579	981	Basic
49	Wabash loam	4,445	7,314	88,423	917	Basic
48	Wabash silty clay loam	2,626	4,710	69,279	981	Basic

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moves upward in the soil. If the surface soil is acid, lime will need to be applied.

GREENHOUSE EXPERIMENTS

Three greenhouse experiments were carried out on soils from Madison county to secure some indications of the fertilizer needs of the soils and to determine the value of the application of certain common fertilizing materials. Two of these experiments were carried out on the Tama silt loam, the most important soil type in the county, and one on the Clinton silt loam, a minor type.

The plan followed in all these experiments was the same and the amounts of the various materials applied were the same as those employed in the field experiments; hence the results of the greenhouse tests may be considered to indicate quite definitely the results which will be secured in the field. Manure was applied at the rate of eight tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil as indicated by the Veitch test and two tons additional were supplied in order to put the soil in the best condition for crop growth. Rock phosphate was applied at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in these experiments, but the wheat yields were secured in only one of the tests. The clover yields were secured in all cases but in two of the experiments only the green weights were taken.

The results of the experiment on the Tama silt loam are given in table VII, the figures being the averages of the yields on duplicate pots. The application

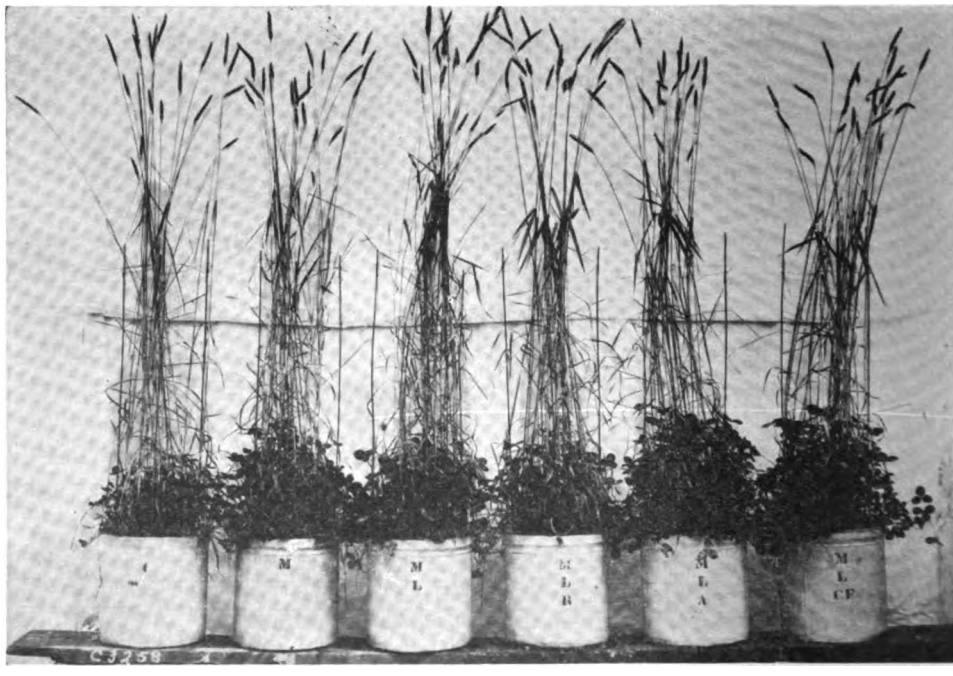

Fig. 2. Greenhouse experiment with wheat and clover on Tama silt loam.

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TABLE VII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MADISON COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Dry weight of clover in grams
1	Check	13.0	27.21
2	Manure	18.0	40.82
3	Manure+lime	....	45.36
4	Manure+lime+rock phosphate	21.7	47.62
5	Manure+lime+acid phosphate	24.0	63.50
6	Manure+lime+complete commercial fertilizer	20.0	65.77

of manure brought about a distinct increase in the yields of both the wheat and the clover, the gain being particularly evident on the clover crop. Lime in addition to manure increased the yield of clover quite distinctly. The yield from this treatment on the wheat crop was evidently abnormal and is not included. The phosphate fertilizers all gave increases in crop yields, the acid phosphate showing up the best on the wheat, while the complete commercial fertilizer was slightly superior to the acid phosphate in the case of the clover. With the latter crop, the acid phosphate and complete brand gave very much greater effects than the rock phosphate. In the case of the wheat the rock phosphate and complete commercial fertilizer gave almost the same results.

It is evident from these results that manure is a very valuable fertilizing material for use on this soil and that it should be applied in as large amounts as practicable. Lime added with manure had an important influence on clover and would undoubtedly benefit other legume crops used in the rotation. Ordinarily this material would not benefit the grain crops of the rotation except indirectly. Rock phosphate, acid phosphate and a complete commercial fertilizer all gave increases in crop growth and indications are that phosphorus may probably be used on this soil type with profit. It seems that the acid phosphate is somewhat superior to the other materials but definite conclusions should not be drawn from this experiment as other tests may indicate somewhat different results.

The second greenhouse experiment was carried out on the same soil type from Madison county and the results are given in table VIII. Again it is apparent that the application of manure increased the crop growth on the Tama silt loam. Lime in addition to manure increased the clover yield, rock phosphate had practically no effect, while the acid phosphate and complete commercial fertilizer showed a very large gain in crop growth. These results confirm those secured in the preceding test and show the value of manure and lime on this soil type and indicate also the possibility of using acid phosphate or a complete commercial fertilizer profitably. The results seem to show that the acid phosphate is of more value than the other materials.

TABLE VIII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MADISON COUNTY

Pot No.	Treatment	Green weight of clover in grams
1	Check	131.54
2	Manure	140.61
3	Manure+lime	149.68
4	Manure+lime+rock phosphate	149.68
5	Manure+lime+acid phosphate	190.51
6	Manure+lime+complete commercial fertilizer	181.44

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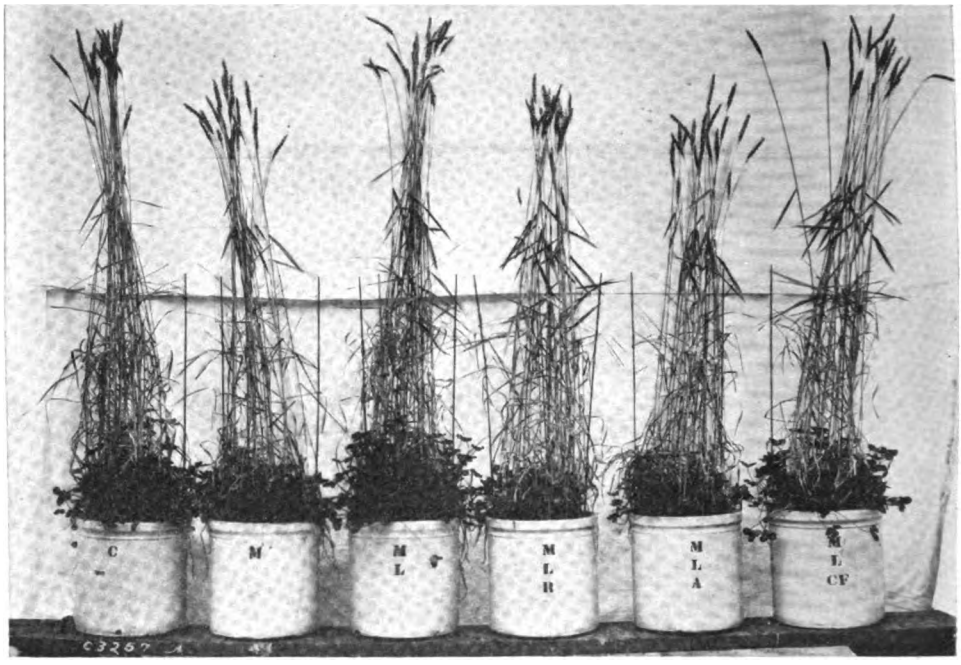

Fig. 3. Wheat and clover on Clinton silt loam, Madison county.

The third greenhouse experiment was carried out on the Clinton silt loam and the results of this experiment are given in table IX. The value of manure showed up very distinctly in this experiment, a very large increase in the yield of the clover being secured. Lime brought about a further increase in crop yield and all the fertilizing materials increased the clover to a considerable extent. The rock phosphate showed up a larger effect than the other materials. The acid phosphate appeared somewhat better than the commercial fertilizer. However, the differences in the effect of these matrials are not large enough to be very distinctive. It would seem from the experiment that there is no doubt but that phosphorus fertilizers will probably yield profitable returns when applied to this particular soil. Just which material should be used must be determined by more extensive field experiments. There is no question but that manure is a particularly valuable fertilizing material for this soil and that lime should be used when the soil is acid, especially if the best growth of legumes is to be secured.

These greenhouse experiments as a whole indicate quite definitely the value of manure as a fertilizer on the soils of this county and they show also the

TABLE IX. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, MADISON COUNTY

Pot No.	Treatment	Green weight of clover in grams
1	Check	181.44
2	Manure	206.38
3	Manure+lime	213.19
4	Manure+lime+rock phosphate	258.55
5	Manure+lime+acid phosphate	247.21
6	Manure+lime+complete commercial fertilizer	235.89

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large value which may be secured by using lime on acid soils. There are indications of value from the use of phosphorus and it is urged that tests with various phosphorus fertilizers be carried out on individual farms in order to determine the desirability of using these materials.

FIELD EXPERIMENTS

Several field experiments are just being started in Madison county and hence it will be several years before the results of these experiments will be sufficiently complete so that conclusions can be drawn from them. The data secured in these field tests will be published later in a supplementary report. For the present the results secured in other counties on the same types of soil must be depended upon primarily for supplying indications of the needs of the soil of the county in general.

An experiment on the Tama silt loam, the main soil type in Madison county, has been under way for several years in Black Hawk county. The results which have been secured in this field may be considered to indicate quite definitely the results which would be secured with the same treatments in Madison county. Hence the results of this field experiment are given here to further support the greenhouse data and laboratory tests in showing the treatments which will prove most profitable on the soils of Madison county. This field experiment is laid out on land which is entirely representative of the particular soil type. It is located permanently by the installation of corner stakes and every precaution is taken in the application of fertilizers and in the harvesting of crops to be sure that accurate results are secured. The plots are 156′ 6″ by 28′ in size, representing one-tenth of an acre.

In that portion of the test reported here, the livestock system of farming is represented, manure being applied along with other fertilizing materials. The other fertilizers used include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied at the rate of eight tons per acre once in a four-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation. Acid phosphate is used at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer has been used at the rate of 300 pounds per acre annually.

THE HUDSON FIELD

The Hudson field was laid out in 1917 on the Tama silt loam near Hudson in Black Hawk county. The results obtained on this field in 1918, 1919, and 1920 are given in table X. Crop yields were not secured in 1921, owing to an oversight on the part of the cooperator.

The yields of corn and oats are apparently influenced to a considerable extent by the fertilizer treatment. Applications of manure, lime and phosphorus fertilizers all affected, to some extent, the crop yields. Manure seemed to be of particular value, and it is particularly interesting to note the beneficial effect of lime when applied along with the manure. Ordinarily this material would not be expected to increase the yields of corn and oats, but beneficial

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TABLE X. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Corn bu. per acre 1920
1	Check	45.8	47.6	53.2
2	Manure	49.3	54.7	62.8
3	Manure+lime	54.4	59.2	67.4
4	Manure+lime+rock phosphate	56.5	64.9	73.3
5	Manure+lime+acid phosphate	57.4	62.2	73.3
6	Manure+lime+complete commercial fertilizer	58.5	57.5	72.4

effects were secured on both crops in this experiment. The legume grown in the rotation is usually expected to show the large effect from the use of lime and frequently the only effect which that material exerts. It seems evident that lime must exert some indirect effect on this soil which results in greater crop growth.

Rock phosphate, acid phosphate and a complete commercial fertilizer all brought about beneficial effects on the crop grown, the relative value of the three materials being somewhat different on the two crops and somewhat different also on the same crop in different seasons. It is quite probable that phosphorus fertilizers might be used on this soil in many cases at the present time with beneficial effects. It is not possible, however, as yet, to choose the particular phosphorus fertilizer which should be employed. More complete data must be secured with these materials before definite, comparative statements can be made. For the present it can only be recommended that phosphorus fertilizers be tested and if they show value under the particular conditions, then the same material may be used with profit on larger areas.

In general this field experiment seems to lead to conclusions which very largely confirm those drawn from the greenhouse data and it emphasizes the need and value of manure and lime when applied to this soil and suggests the possible value which may be secured from the use of a phosphorus fertilizer.

THE NEEDS OF MADISON COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The suggestions which are made in this section of the report regarding the most desirable treatments for the soils of Madison county are based upon the experimental information secured in the laboratory and greenhouse and upon the results secured in a field test carried out in another county on a soil type which is the same as the major type in this county. When the field experiments in Madison county have been under way for several years, more definite recommendations may undoubtedly be made. It should be emphasized, however, that no suggestions are offered here regarding soil treatment which have not been proven definitely to be of value by considerable practical experience among the farmers of the county and which may be put into operation under any farm conditions.

The suggestion is frequently made that farmers test the value of certain fertilizer treatments on their own farms and this is the only suggestion which

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can be offered in the case of the use of phosphorus fertilizers, altho experiments indicate that they are of value. Farmers may apply a phosphorus fertilizer to small areas and thus determine for their own conditions which carrier will yield the largest effects and which will give the greatest crop growth in comparison with the cost of the material. In the case of the complete commercial fertilizer, the value of the material must be compared with that of a phosphate carrier, inasmuch as the former materials are much more expensive and it is not deemed likely that the nitrogen and potassium contained in the complete brand would be of economic significance. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid in the planning and carrying out of field tests and any farmers who are interested should communicate with the Soils Section.

LIMING

Many of the soils of Madison county are acid and in need of lime. Practically all of the important upland types need lime and most of the terrace soils are acid. The bottomland soils, however, all show a basic reaction thruout the soil section, except in the case of the Wabash silt loam where the subsoil shows acidity. The Lindley loam is the only upland type which is not acid and this is only true in the surface soil. The Grundy silt loam shows a basic reaction in the subsoil. There is only one instance where there is any considerable quantity of inorganic carbon present and that is in the surface soil of the Lindley loam. In all the other cases where the reaction is basic, there is only a small amount of inorganic carbon present and in most cases the content is so small that it can only be given as a trace. It is apparent, therefore, that even on those soils in the county which are not acid now, lime will be needed in the very near future and would probably prove of value when legumes are grown on these soils at the present time. In fact, the reaction of the soils is so slightly basic that the various types should undoubtedly be tested for acidity at the present time.

The figures given in table IV show the needs of the surface soils which are acid at the present time, but these figures merely suggest the needs of the soils and before lime is applied tests should be made of the individual soils. The lime requirement of soils is extremely variable and even average figures secured from a large number of tests will not show accurately the needs of a particular soil. Variations may occur even in the same field and if the proper amount of lime is to be applied in any individual case, that particular soil should be tested. The need of lime on soils is particularly evidenced when legumes are to be grown. Clover and alfalfa will not make their best growth unless lime is present in the soil. Other legumes are quite generally sensitive to lack of lime and frequently additions of lime will bring about increases in the yields of corn and small grains, altho ordinarily such crops are not expected to show any benefit from the use of this material.

The value of lime on soils is not due entirely to its direct effect on crop growth, but it is due also to an improvement in the physical and bacteriological conditions in the soil. Not only does lime supply plant food which is needed by all crops, particularly by legumes, but it also makes heavy soils more open and

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porous, it makes light soils less porous and less subject to losses by leaching, and it brings about greater bacterial activities and hence greater production of available plant food. The value of applications of lime to acid soils is probably due in most cases to all these effects combined, but there are some instances where the bacteriological effects are probably the most significant. There is always a secondary effect of liming on corn and small grains if the legume crop of the rotation is increased in growth, owing to the fact that the greater legume residues would bring about greater yields of grain. The beneficial effects of liming acid soils has been demonstrated by many experiments and much farm experience.

The upland soils of Madison county will undoubtedly respond to applications of lime when they are acid and the experimental data and experience of farmers in the county confirms this conclusion. It is not an expensive proposition to apply lime to soils and the beneficial effects will more than warrant the outlay. The farmers of Madison county should test their soils for acidity or they should have their soils tested by the Soils Section of the Iowa Agricultural Experiment Station and they should then apply the amount of lime which the test shows to be necessary. In this way they may be sure that they are putting their soils in the best condition for the growth of general farm crops and that they are insuring the best growth of legumes.

Furthermore, it is very important that soils be tested for acidity and lime requirements at regular intervals. When soils are cultivated there is a constant removal of lime thru washing away in the drainage water and thru utilization by crops. If the soil is well drained, as is very necessary for good crop growth, the loss of lime in the drainage water may be considerable. Light textured soils will lose their lime more readily that heavier textured types, owing to more rapid washing away. One test for acidity and one application of lime to a soil, therefore, will not be sufficient for all time. Probably a test should be made at least once in a four-year rotation and the lime needed be applied preceding the clover or legume crop of the rotation.

Limestone is the most satisfactory material for use in remedying acidity in soils and it may be secured in various parts of the state. Lists of companies that are prepared to supply limestone for agricultural purposes are given in circular 58 of the Agricultural Experiment Station. Further information regarding the use of lime on soils, losses by leaching and other information along this line is given in bulletin 151 of the Iowa Agricultural Experiment Station.

MANURING

There is no excessive amount of organic matter in any of the soils of Madison county and in some instances the supply of this material is far too low to provide the best conditions for crop growth. An increase in the organic matter content of soils is brought about mainly thru the application of farm manure, one of the most important farm practices for the soils of this county. The beneficial effects of this material on crop yields are very definite and well known. There is no other fertilizing material which has proved nearly as valuable as farm manure.

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The experiments reported in the previous pages and the practical experience of many farmers are in absolute agreement in showing large crop increases secured when farm manure is used. On those soils where the supply of organic carbon is low, as indicated in the tables, beneficial effects of manure are particularly evident, but even where the soil seems to be fairly well supplied with organic matter, additions of farm manure are of large value. Thus the Tama silt loam, for instance, altho not strikingly deficient in organic matter, is increased in productiveness to a considerable extent thru the application of manure. The farmers of Madison county should evidently take special precautions to be sure that the manure produced on their farms is carefully preserved and applied to the soil if satisfactory crop growth is to be secured and the soils are to be kept permanently fertile.

The beneficial effects of applying manure to soils are due to the influence on the chemical, physical and bacteriological conditions in the soil. Manure returns a large part of the plant food which has been removed from the soil by the crops grown and hence returns valuable plant food constituents, thus lengthening the life of the soil and prolonging the time before any one of the essential plant food constituents becomes deficient.

Light sandy soils are made more retentive of moisture, less open and porous and less subject to losses by leaching when manure is applied. Heavy clay soils are opened up and made less impervious and better aerated by the addition of manure.

Enormous numbers of bacteria are contained in manure and are therefore applied to the soil when this material is used as a fertilizer. The effect of the addition of these bacteria is to bring about a large increase in available plant food production. The better physical conditions of the soil also stimulate bacterial action and there is more decomposition and more soluble plant food prepared for the use of crops. There are many instances where the bacteriological effects of manuring are of main importance. On dark colored soils where the organic matter supply is not low, the bacterial effects of manuring are probably of the greatest importance.

In general, however, it is believed that increased crop yields secured by the use of manure are due probably to a combination of the bacterial, chemical and physical effects. In the case of Madison county soils, there are several instances where the bacterial effects of manure would undoubtedly be of major importance. There are other cases where the plant food addition would be of particular value, especially if permanent fertility is considered.

The fertilization of the soils of Madison county should begin with the use of manure. If other fertilizers are to be employed they should be used in addition to manure in order to give the best results. The use of manure is, of course, dependent very largely upon the system of farming and if livestock farming or general farming is not practiced, then some other material must be utilized in place of manure.

The value of manure is so great that it is of utmost importance to preserve the manure as produced on the farm and prevent losses which lessen its value when applied. If it is stored in loose heaps and exposed to the weather and the leaching action of rains, 70 to 90 percent of the valuable material in it

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may be lost. When such losses occur, increases in crop yields are very much smaller. Hence improper storage may lead to actual economic loss on the farm. The farmers who are not taking precautions in handling the manure produced on their farms are actually reducing their own incomes.

Manure may be stored in various ways and no one method can be suggested as desirable under all conditions. It may be stored in a covered yard or in a pit, or it may be composted, or some other method adapted to local conditions may be followed. In general, it may be said that any method which keeps the manure moist and compact and protected from the weather will be of large value in preserving the fertility of the manure. Occasionally it may be best to apply manure as produced to the land. When this is possible there is no need of storage. There are many instances where this method cannot be followed, and then the manure should be very carefully stored until applied. When it is recalled that carefully stored manure may return to the land 75 to 80 percent of the plant food which has been taken out by the crops grown, the importance of taking care of this material and applying it to the land with a minimum loss can readily be seen.

On the average livestock farm the production of manure will not permit of any large application and the usual amount applied is 8 to 10 tons per acre once in a four-year rotation. On very light textured soils or light colored types, larger applications of manure may sometimes be made with profit, but for general farm crops it is not desirable to apply more than 16 to 20 tons per acre. The average application will undoubtedly prove of quite as large value on the soils of Madison county in most instances as if larger amounts were used. In general it may be said that the best practice is to make applications of manure at regular intervals and in reasonable amounts in order to provide for the best growth of general farm crops and to keep all the soils of the farm productive.

GREEN MANURING

On the grain farm some material must be utilized in place of farm manure to keep up the supply of organic matter in the soil and that is also true of many livestock farms where sufficient manure is not produced. In both cases green manuring is most desirable, either as a substitute for manure or as a supplement to it. Leguminous crops are the most desirable for green manures because when well inoculated they are able to take up nitrogen from the atmosphere and store it in the soil for the use of subsequent crops. Such materials, therefore, not only maintain the organic matter in the soil, but they also serve as nitrogenous fertilizers. Nonlegumes are sometimes used as green manures and they are valuable from the organic matter standpoint, but they do not add nitrogen and hence there are very few cases where their use is preferable to that of legumes. When the organic matter content of the soil is low, the nitrogen supply is usually deficient also, and if green manuring is to be practiced it is in general much more desirable to use a legume. Several legumes may be used as green manures and some particular one may be chosen to fit in with almost any rotation. Green manuring should not be followed blindly or carelessly as undesirable effects may occur if the soil conditions are not such that the green material will be readily decomposed. Advice regarding green manuring under special soil conditions will be given by the Soils Section upon request.

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CROP RESIDUES

It is very important in all systems of farming to utilize fully crop residues such as straw and stover. Frequently these materials are burned or otherwise destroyed with large losses of valuable material. The farmer who follows this method of disposing of his crop residues is actually wasting valuable fertility constituents. On the livestock farm the materials may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil, or they may be stored and allowed to decompose to some extent before application. It is of particular importance, of course, to return all crop residues to the land when grain farming is practiced, as in this case there is practically no manure available for use. On the livestock farm the crop residues are a valuable supplement to the manure.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Madison county have shown that phosphorus is not present in any of the soil types in the county in any considerable amounts and in most cases the content of this element is so low that it is evident that phosphorus fertilizers will be needed if the soils are to be kept permanently fertile. Furthermore, there is evidence that the application of phosphorus might be of value on some of the soils of the county at the present time.

Where the total supply of phosphorus in soils is low, it is quite probable that there is an insufficient production of the element in an available form to keep crops supplied and hence, while the analyses of the soils do not show definitely the need of phosphorus, they do indicate that available phosphorus is probably deficient in many cases. The greenhouse tests on the soils of Madison county and the field tests in another county on one of the main soil types in Madison county indicate rather definitely the desirable effects of phosphorus. It is recommended that farmers test the need of phosphorus at the present time on small areas, thus determining the increases in crop yields which may be secured under their particular farm conditions. Until the field experiments which have been started in the county are completed, this is the most satisfactory recommendation which can be made.

Either of two phosphorus fertilizers may be used, acid phosphate or rock phosphate. Acid phosphate is the more expensive, but it contains phosphorus in an available form and this element is therefore more readily utilized by crops. Rock phosphate, while cheaper, has a low rate of availability and considerably larger applications must be made. It is not possible yet to suggest which of these materials should be employed and farmers are urged to use both materials in tests on their farms. Relative yields secured when these materials are applied would indicate which will prove the most profitable, but the yield alone is not sufficient to warrant a choice, as comparisons of the value of the two materials depend also upon the cost of the application. It should be emphasized also that yields should be secured for several years in order to arrive at satisfactory comparisons, as rock phosphate, while not rapidly available the first year after application, becomes more largely available later. Acid phosphate is immediately available and hence is applied annually in the spring. Rock phosphate is applied usually once in a four-year rotation and hence yields of

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crops should be secured for that period if satisfactory comparisons are to be made. It is frequently desirable to apply acid phosphate to a small area and thus determine the need of phosphorus on a particular soil and later rock phosphate may be tested to determine its relative value in comparison with further applications of the acid phosphate.

Farmers may carry out tests with these materials on small areas with little difficulty. Directions are given in circular No. 51 of the Iowa Agricultural Experiment Station.

Most of the soils types in Madison county are fairly well supplied with nitrogen, but in any case an addition of this element must be considered in planning systems of permanent fertility. There is a constant loss of nitrogen from soils by removal in the drainage water and by utilization by the crops grown and hence there must be a return of nitrogen to soils if the proper amount of this element is to be maintained. Even altho many of the soils in the county are not strikingly in need of nitrogen at the present time, this element will be needed in the future and precautions should be taken to keep up the supply by regular additions of materials containing nitrogen.

Farm manure is the most important fertilizing material for supplying nitrogen, and it may return a large portion of the nitrogen removed by the crops grown. If the manure produced on the livestock farm is carefully preserved and applied to the soil, the decrease in nitrogen content in the soil will be rather slow, but even under livestock farming conditions with a careful utilization of the manure, the nitrogen content of the soil will not be maintained. On the grain farm where manure is not available for use, some other source of nitrogen must be employed. Under both these systems of farming the practice of green manuring will provide it. It is particularly important on the grain farm.

Legumes should be used in green manuring, as they have the ability when well inoculated to utilize the nitrogen of the atmosphere and when turned under in the soil, they increase the supply of nitrogen. Nonlegumes are not of value as nitrogenous fertilizers, but well inoculated legumes have proved the cheapest and most efficient nitrogenous materials which can be employed.

It is important to note that the mere growing of a legume will not be sufficient to build up the nitrogen content of the soil. If the crop is cut off, nitrogen is removed and while the soil will not be depleted as largely as would be the case with a grain crop, still no nitrogen will be added. Occasionally the seed only of a legume crop is removed and the remainder is turned under. This method may add considerable nitrogen. Legumes should undoubtedly be used in all rotations and it is very necessary that a part or all of the crop be turned under in the soil as a green manure if the nitrogen content of the soil is to be kept up. Occasionally legumes are employed as catch crops and when used in this way they may also serve to supply nitrogen as well as organic matter to the soil.

The proper utilization of crop residues is very important under all systems of farming to cut down the losses of nitrogen from the soil; such materials may prove of considerable value from the nitrogen standpoint, supplementing the use of farm manure or green manures. Commercial nitrogenous fertilizers are not recommended for general farm crops in this county, as it is believed that

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leguminous green manures are much cheaper and quite as effective. Small amounts of commercial materials may be applied as top dressings to stimulate the early growth of crops, but they are usually too expensive. If they prove of value on small areas they may be employed, however, without any fear of injuring the soil. Farmers who are interested may test the use of such fertilizers, determining for their own conditions the economic value from the application.

Many analyses have been made of the soils of the state and in all cases large amounts of potassium have been found. There is no doubt, therefore, but that there is a large supply of potassium in all the soils of Madison county and it is not likely that potassium fertilizers will prove of value in any case for general farm crops. Such materials might prove profitable if applied in small amounts as top dressings, but their general use cannot be recommended. If the soils are well drained and cultivated, supplied with lime and organic matter, the rapid production of available potassium, sufficient for crop needs, is almost certain. Farmers who are interested in the use of potassium fertilizers may test their application to small areas and if profitable returns are secured, applications may be made to large areas without any injury to the soil.

Complete commercial fertilizers are being tested in the field experiments now under way in the county and their value is being compared with that of phosphorus carriers. Their use at the present time cannot be recommended and the indications from the experiments which have been carried out are that phosphorus fertilizers will prove more profitable. The complete brands are rather expensive and if the soils do not need potassium or nitrogen, a phosphorus carrier would undoubtedly prove more profitable. If tests prove their application of value there is no objection to their use. It is merely a question of their economic value in comparison with phosphorus. Farmers who are interested in complete materials should test their use on small areas before making any extensive application.

DRAINAGE

The soils of Madison county are in general quite adequately drained. The natural drainage system of the county is well developed and there are very few areas where excess water is not rather readily removed. One of the upland types, however, the Grundy silt loam, is rather poorly drained, occupying level upland areas and having a rather stiff subsoil. The areas on the map where this soil occurs are the areas which are in need of drainage. There are a few other areas where drainage is needed, but they are not at all extensive. The installation of tile frequently would prove of considerable value in making the Grundy silt loam more productive.

Where the soil is poorly drained no other treatment will prove of value and even tho the expense of tiling is considerable, it will be well warranted by the increased crop yields secured. Many of the bottomlands in the county are not well drained, but they are also subject to overflow and if they are to be brought under cultivation they must be protected from overflow as well as provided with adequate drainage. In most cases these areas are kept in pasture and no attempt is made to cultivate them.

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THE ROTATION OF CROPS

It is very necessary for the continued fertility of all soils that some rotation of crops be practiced. Continuous cropping always leads to a rapid reduction in fertility and it also has proven economically undesirable. Even if a money crop is grown continuously, the reduction in crop yields will be so rapid that the value of all the crops grown over a period of years will be much greater where a rotation is practiced, in spite of the fact that less valuable crops are included. Various rotations may be used under different conditions and no one rotation should be recommended for general use. In fact, it may be said that almost any rotation may be practiced provided it includes a legume and a money crop. No specific experiments have been carried out in Madison county with rotations, but the following may be given as examples of desirable rotations which have been used thruout the state.

I. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.)
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy.)
Fourth Year—Clover. (If timothy was seeded with the clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain.)
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not likely to be subject to erosion, while heavy soils, such as loams, silt loams and clays, may suffer much from heavy or long-continued rains. Loess soils are very likely to be injured by erosion when the topography is hilly or rough and it is this group of soils

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which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts made more costly and inconvenient.

Erosion occurs to a considerable extent in Madison county. The Shelby loam and the Lindley loam, the two drift types, are subject to considerable washing; in fact they have been formed because of the washing away of the surface covering of loess. The Clinton silt loam of the loessial upland is frequently considerably eroded and occasionally there is some gully formation in the Tama silt loam. The Jackson silt loam of the terrace is somewhat eroded and both residual soils are badly washed. It is very necessary that care be taken in handling the soils of this county that they be protected from the injurious effect of erosion and from the methods suggested here some one may be chosen which will serve under the particular conditions.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicate to "dead furrows," to small gullies, to large gullies, to bottoms, and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows, and in level areas where the soil is deep this "plowing in" process may be quite effective. In the more rolling areas, how-

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ever, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The method consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in dead "furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainage ways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

"Staking In." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward is left near the top. This heavy branch is caught between a fork in the lower part of the brushpile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which

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keeps it from being washed away as readily by the action of a large volume of water. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

A modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" has been applied and hence it is mentioned

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separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an upstream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainage ways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

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Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placd here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLAND EROSION

Erosion frequently occurs in bottomlands and especially where such low-lying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general, it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land, or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues, such as straw and corn stalks, may also be turned under in soils

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to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years, is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also quite desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proved quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil will be reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN MADISON COUNTY*

There are 15 individual soil types in Madison county and these are divided into five large groups according to their origin and location. These groups are known as drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils.

DRIFT SOILS

There are two drift soils in the county, classified in the Shelby and Lindley series. Together they cover almost one-fourth of the total area, 24.2 percent of the county.

SHELBY LOAM (79)

The Shelby loam is the most extensive drift soil in the county and the second largest type, covering 19.9 percent of the total area. It occurs in all parts of

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

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the county, occupying the steeper slopes between the bottomlands and the upland areas. It occurs in narrow continuous strips that extend back along the valleys of the smaller streams on the hillsides adjoining the Tama silt loam of the upland. The most extensive areas of the type are found in the southwestern part of the county and in the northeastern section.

The surface soil of the type is a brown to dark brown mellow loam 6 to 14 inches in depth. Below that point the soil is a stiff, waxy yellowish-brown to light brown gritty clay or sandy clay mottled with yellow and drab. Below 30 inches the subsoil frequently consists of a light colored coarse sand mixed with gravel. Variations in the surface soil are common. The texture varies from a fine sandy loam to a silt loam. Occasionally there are shallow layers of sand and gravel separating the soil and subsoil. Stones are of frequent occurrence and streaks of calcareous material are occasionally found. The depth of the surface soil is variable on the gentler slopes, being 12 to 14 inches deep, while on the steeper slopes the soil has been removed considerably and the yellowish-brown silty clay loam subsoil is exposed. Along some of the smaller intermittent drainageways, narrow strips of colluvial material are included with the type, as they were too small to be shown on the map. Small areas of silt loam are included, the drift material appearing at a depth of 18 to 22 inches. On the south slopes to the streams, pebbles, stones, gravel and small boulders are occasionally found. On the hillsides, ridges and knolls a fine sandy loam sometimes occurs and these areas are included with the type, owing to their small extent. They are usually characterized by pockets of coarse sand and gravel. Along the southern boundary of the county directly south of East Peru there is an area of typical Shelby fine sandy loam. Another area occurs in the northern part of the county directly east of Earlham. These are not separated owing to their small extent.

Fig. 4. Shelby loam in Madison county is used largely for pasture.

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In topography the Shelby loam ranges from gently rolling to hilly or rough and the soil is well drained. It is subject to destructive erosion and may be badly washed in the more rolling areas.

About 75 percent of the smoother areas of this type are under cultivation, the remainder being in pasture. Most of the typical Shelby loam, however, is used for pasture or hay land. Originally it was partly timbered with oak, hickory, elm, hazel and underbrush. Some of the slopes are still forested. When the type is farmed, corn, oats and hay are the main crops grown. Yields of corn amount to 20 to 40 bushels per acre; oats 20 to 30 bushels and hay 1 to 1½ tons.

Fairly satisfactory crop yields are secured on cultivated portions of the type but they would be increased thru the addition of farm manure in liberal amounts, as the organic matter content of the type is not high. Phosphorus fertilizers would undoubtedly prove of value and in some instances the addition of lime would be needed, altho the soil is not always acid in reaction. The type is subject to extensive washing and when cultivated care should be taken to prevent the removal of the surface soil. There are many areas where cultivation is impracticable and the soils should undoubtedly be utilized for pasture or hay land. Excellent pastures may be maintained on much of the rougher areas of the type and this is undoubtedly the most profitable method of handling such rough areas as are of frequent occurrence.

LINDLEY LOAM (65)

The Lindley loam is a minor soil type in the county covering 4.3 percent of the total area. It occurs on the slopes to the streams separating the areas of Clinton silt loam on the upland from the bottomland types. It is found mainly along the south slopes of North river, Cedar creek, on both sides of Middle river and in extensive areas along Clanton creek. The areas of the type are all narrow and there are no extensive occurrences.

The surface soil of the Lindley loam is a light grayish-brown to brown loam extending to a depth of 6 to 12 inches. It is underlaid by a light brown or yellowish-brown tenacious, gritty sandy clay loam to sandy clay, in many places mottled with yellowish-brown and grayish-drab. Gravel and coarse sand frequently occur in the subsoil and some lime nodules are occasionally present.

Variations occur in the surface soil, the texture ranging from a silt loam or silty clay loam to a fine or coarse sandy loam. One-fourth of a mile south of Hanley there is an area extending to the bottomland along Clanton creek where the soil is a fine sandy loam to fine sand of a light yellowish-brown color. In the more heavily timbered areas the surface soil may be a mellow black silt loam 2 to 5 inches in depth. In small depressed areas there are occasionally layers of silt loam or silty clay loam several inches in depth. These minor variations of the type are all too small to be mapped separately.

In topography the Lindley loam is rolling to steep and abrupt and the soil is subject to serious washing. The type is well drained, while surface drainage is excessive. In many of the rough areas much of the surface soil has been washed away, and the underlying subsoil material is exposed.

The Lindley loam is mainly utilized for pasture and only a small part of the type is under cultivation. Much of it is forested with white and black oak,

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hickory, ash, hazel, sumac and red haw. On the cultivated areas the chief crops grown are corn, oats and hay. Corn yields 20 to 40 bushels per acre and oats 25 to 35 bushels.

When this type is cultivated it should receive liberal applications of farm manure and if this material is not available, leguminous green manure crops would be of value. The type is low in organic matter and needs to be built up in this constituent. It may be acid in reaction in some cases, altho the particular sample analyzed in this report showed a high content of lime. The occurrence of lime in the soil is extremely variable and it should be tested before legumes are grown. Phosphorus fertilizers would undoubtedly prove of value and tests are recommended for these materials to determine their value on general farm crops. It is particularly important that the type be protected from erosion, as serious washing occurs over large areas. In the rougher areas the type should undoubtedly be kept in pasture and that method of handling it will prove the most satisfactory.

LOESS SOILS

There are three loess soils in the county, classified in the Tama, Clinton and Grundy series. Together they cover 63.7 percent of the total area of the county.

Fig. 5. Valley of Clanton creek west of East Peru. The bottomland soil is Wabash loam, with Lindley loam and Sogn stony silt loam on the bluffs.

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TAMA SILT LOAM (120)

The Tama silt loam is the largest individual soil type in the county as well as the largest loess soil. It covers slightly over half of the total area, 50.3 percent. It is found on the uplands in all parts of the county, the most extensive areas occurring in the northwestern quarter of the county. It is the main type on the more gently rolling uplands and is very largely separated from the bottomlands by the rolling to rough areas of Shelby loam. In the northwestern part of the county, the loess is very deep and the topography is very slightly rolling. In the remainder of the county the type is more noticeably rolling in topography and not quite so deep.

The surface soil of the Tama silt loam is a dark brown mellow silt loam 8 to 20 inches in depth, averaging about 14 inches. The subsoil is a yellowish-brown to brown, compact, friable, heavy silt loam to light silty clay loam, becoming heavier at the lower depths. In the lower subsoil there is often a grayish cast and mottlings of yellowish-brown are occasionally found. Some reddish-brown iron stains also occur. In the northeastern and southwestern parts of the county where the surface soil is shallower, varying from 8 to 14 inches in depth, the soil is somewhat lighter in color at the surface, being almost a grayish-brown and the subsoil is mottled with yellow thruout, mottlings being more pronounced at the lower depths. Rusty brown iron concretions are usually present. In the extreme southeastern corner of the county near Truro and St. Charles, the soil is more typical and resembles that found in the northwestern part of the county. The boundary lines between the Tama and the Grundy silt loam, which is usually more level in topography, are frequently very difficult to draw and in several instances are more or less arbitrary. The Tama silt loam topography is usually gently rolling but may become almost level in certain areas.

About 95 percent of the type is under cultivation and the remainder is utilized for pasture. There is very little of the type that was ever timbered. It has been developed, apparently, under prairie conditions. Corn is the most important crop grown, other crops of value including oats, wheat, timothy and clover. Corn yields 35 to 70 bushels per acre, averaging about 45 bushels. Wheat produces 20 to 30 bushels per acre, the winter varieties being grown almost entirely. Clover and timothy mixed constitute the principal hay crop and the yields range from 1 to 3 tons per acre. Rye, barley, millet, sorghum, vetch, rape and Sudan grass are other crops which are grown to some extent. Fruit and vegetables are produced for home use and excellent yields of potatoes are secured.

The Tama silt loam is naturally a rather productive type but will respond, in many cases, to applications of various fertilizing materials. Applications of farm manure are always of value and lead to increased crop yields. This material should be applied in as large amounts as practicable for this type in order not only to increase crop yields, but to keep up the supply of organic matter. Where manure is not produced, the leguminous crops should be turned under as green manures. The Tama silt loam is acid in reaction and applications of lime are necessary to permit of the best growth of legumes. The soil should be tested for acidity at regular intervals and lime applied as needed.

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The phosphorus content of the soil is not high and phosphorus fertilizers will undoubtedly be needed in the future if they do not prove of value at the present time. There are indications from the greenhouse experiments which have been referred to earlier in this report, that phosphorus fertilizers may prove of value on this soil. Field tests in other counties indicate also the possible value from applications of phosphorus. It is urged that farmers test the value of rock phosphate and acid phosphate on their own farms in order to determine whether phosphorus fertilizers are of value under their particular conditions and, if so, which material should be employed.

CLINTON SILT LOAM (80)

The Clinton silt loam is the third largest soil type in the county and the second most extensive loess soil. It covers 9.3 percent of the total area of the county. It occurs on the tops of the higher ridges adjacent to the larger streams. It is most extensively developed along Middle and North rivers and Clanton creek. The largest area is found between Clanton creek and Middle river in the southeastern part of the county. The type occurs only rarely in the northwest and southwest sections of the county. Near the heads of the streams and along the minor tributaries of the larger rivers, the type occurs only in small patches on the tops of the ridges.

The surface soil of the Clinton silt loam is a light grayish-brown, smooth floury silt loam to a depth of 7 to 12 inches. At that point it becomes a more compact brown to yellowish-brown heavy silt loam faintly mottled with gray. Between 14 and 18 inches the subsoil becomes a very compact yellowish-brown silty clay mottled with light gray and grayish-brown.

In topography the Clinton silt loam is gently rolling to hilly and the drainage is entirely adequate. The soil is subject to considerable erosion and gullies and ditches are of rather common occurrence.

This type was originally forested with white oak, black oak, elm, hickory, hazel and other hardwood trees. Most of the land is now cleared and utilized for general farming. The principal crops grown are corn, oats, wheat, clover and timothy. Corn yields from 20 to 40 bushels per acre, oats 25 to 40 bushels per acre, hay 1 to 2 tons per acre. Small fruits and tree fruits, strawberries, blackberries, raspberries, cherries, apples and grapes grow very satisfactorily on this soil but they are not produced in sufficient quantities even to supply the local markets. Potatoes and garden vegetables are grown for home use.

The Clinton silt loam is not as highly productive a type as the Tama silt loam and will respond profitably to fertilizer treatments. It is particularly in need of organic matter and applications of farm manure are very desirable and prove extremely profitable. This material should be applied in as large amounts as practicable if the soil is to be built up in organic matter supply and made more productive. If farm manure is not available leguminous green manures should be employed. The soil is acid in reaction and applications of lime are quite necessary if legumes are to be grown. The soil should be tested for acidity and lime applied as necessary. The phosphorus content of the Clinton silt loam is low and phosphorus fertilizers will undoubtedly be needed in the future. They may be of value in many cases at the present time and farmers are urged to test the value of phosphorus on their own farms. In this way

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they may determine whether phosphorus fertilizers will prove of value on their soils and they will also learn whether acid phosphate or rock phosphate will prove the most profitable.

GRUNDY SILT LOAM (64)

The Grundy silt loam is a minor type in the county, covering 4.1 percent of the total area. It is found in all parts of the county, but in comparatively small areas. The largest continuous area is south and east of Winterset. Other areas of considerable size are just west of Winterset and thruout the northwestern quarter of the county, especially in the vicinity of Earlham. It is found on the highest areas of upland, on the level land between the streams or drainage channels, occurring in strips from one-eighth to three-fourths of a mile in width and also in many small patches.

The surface soil of the Grundy silt loam is a dark brown to almost black friable silt loam 8 to 14 inches in depth, averaging about 10 inches. The subsoil to a depth of 18 to 22 inches is a grayish-brown to dark brown silty clay loam with faint yellowish mottlings at the lower depths. Below 22 inches the subsoil changes abruptly into a bluish-gray or grayish-brown silty clay mottled with yellow. In some areas there is a layer of gray silty material, in the subsurface layer between the depths of 8 and 12 inches. Rusty brown to black iron concretions are numerous. The soil is lighter in color and more plastic and tenacious at the lower depths and because of its dense impervious character is locally called "hardpan."

In topography the Grundy silt loam is level to very gently undulating. The drainage is quite inadequate and the installation of tile is very necessary to remove the water which accumulates on the type after each rain.

Practically all of the soil is under cultivation, general farm crops being grown. Corn is the most important crop, yielding about 55 bushels per acre on the average. Under favorable conditions this yield is very much increased.

Fig. 6. Grundy silt loam south of Earlham shows typical topography of this soil.

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Oats yield from 30 to 80 bushels per acre in favorable seasons but are inclined to lodge in wet years. Wheat yields 20 to 40 bushels per acre and hay, usually clover and timothy, yields from 1 to 2½ tons per acre.

The chief need of the Grundy silt loam to make it more productive is adequate drainage. The installation of tile proves distinctly profitable. The soil is acid in reaction and should be limed if clover or other legumes are to be grown. Applications of farm manure are of considerable value on this soil, bringing about increases in crop yields in practically all cases. This is true in spite of the fact that the type is not particularly deficient in organic matter. The content of phosphorus is not high and there are indications that phosphorus fertilizers might prove of value. Tests on individual farms with the use of both rock phosphate and acid phosphate are very desirable in order to determine whether or not phosphorus should be applied to the soil and which particular fertilizer might be employed the most profitably.

TERRACE SOILS

There are four terrace soils in the county, classified in the Waukesha, Bremer, Jackson and Calhoun series. They are all minor in area and together cover only 2.1 percent of the total area of the county.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the largest of the terrace types but it is small in area, covering but 1.0 percent of the total area of the county. It occurs in small areas in various parts of the county, chiefly, however, along Middle river and Clanton creek, the largest areas being found east and south of Winterset and northeast of East Peru. It is found on the terraces joining the soils of the Wabash series in narrow strips.

The surface soil of the Waukesha silt loam is a brown to dark brown mellow silt loam 12 to 20 inches in depth. Below that point it changes to a brown to grayish-brown heavy silt loam to light silty clay loam. The lower subsoil is heavier in texture and lighter in color and mottled with gray. In the more level areas there is a heavy intermediate layer at a depth of 10 to 15 inches consisting of a dark brown silty clay loam.

In topography the Waukesha silt loam is generally level to gently undulating. In some areas the surface topography has been modified somewhat by the streams from the uplands flowing thru. The type is well drained and not at all drouthy. Originally the Waukesha silt loam was forested to a small extent but very few trees remain on it at present.

Practically all of the type is in cultivation, only a few of the smaller areas being utilized for pasture. General farm crops are grown, corn being the most important. Yields of this crop average 35 to 70 bushels per acre. Oats, wheat and clover and timothy are grown to some extent and the yields are very much the same as on the Tama silt loam of the upland. Alfalfa has been grown on small areas and yields 2 to 3 tons of hay per acre.

This soil is quite productive but increases in crop yields are secured thru proper soil treatment. Applications of farm manure are of large value. The soil is acid and lime should be applied as needed, particularly for the growth

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of legumes. The phosphorus content is not high and phosphorus fertilizers would probably prove of value in many cases.

BREMER SILT LOAM (88)

The Bremer silt loam is a minor terrace type in the county, covering 0.7 percent of the total area. It occurs in several areas in various parts of the county, chiefly, however, along Middle river, Clanton creek and North river. The largest areas are found along Middle river between Patterson and Bevington. The other areas are all small in extent.

The surface soil of the Bremer silt loam is a dark brown to black, compact, friable silt loam to a depth of 8 to 12 inches. The subsoil is a dark brown to black heavy stiff silty clay loam changing at 22 to 28 inches into a brown to dark brown plastic clay loam faintly mottled with yellowish-brown and gray. In some areas the subsoil contains reddish-brown to black iron concretions. There are small areas of Bremer silty clay loam included with this type but they have not been separated owing to their small extent.

In topography the Bremer silt loam is level to gently sloping. The surface drainage is fair but the soil is quite generally in need of tiling owing to the heavy character of the subsoil. Practically all of the type is under cultivation, only a small area being in pasture. Corn, oats, wheat and hay are the principal crops grown. Corn yields 35 to 70 bushels per acre and hay 1½ to 2 tons. Yields of wheat and clover are very much the same as on the adjacent uplands.

This type would be benefited particularly by the installation of tile where artificial drainage has not already been provided. It is high in organic matter but small applications of farm manure are of value, particularly on newly drained areas. The soil is acid and in need of lime. It is not high in phosphorus and phosphorus fertilizers might be employed to advantage.

JACKSON SILT LOAM (81)

The Jackson silt loam is a minor type in the county, covering only 0.3 percent of the total area. It occurs in a number of small areas, chiefly along Middle river, the most extensive areas being found in the vicinity of Webster. Smaller isolated areas occur along Clanton creek, North Branch of North river, Grand river and North river.

The surface soil of the Jackson silt loam is a light brown to grayish-brown smooth silt loam extending to a depth of 8 to 12 inches. Below this point it grades into a light brown to yellowish-brown silt loam becoming more compact at the lower depths and streaked with gray. Below 30 inches the subsoil is a very compact, brown heavy silty clay loam slightly mottled with gray. In some areas where the terrace joins the upland, there are small layers and pockets of sandy and silty material in the subsoil and occasionally some sandy material has accumulated on the surface.

In topography the soil is level to gently undulating. It occurs 10 to 30 feet above the bottomlands and drainage is usually quite adequate. It is practically all under cultivation and corn, wheat, oats, timothy and clover are the chief crops grown. Corn yields 30 to 50 bushels per acre, oats 30 to 40 bushels, wheat 15 to 30 bushels and hay 1 to 2 tons. Small fruits and vegetables grow well on this soil and some apples are produced in small orchards.

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Fig. 7. A stretch of level terrace soil,—Waukesha silt loam.

This type is benefited particularly by applications of farm manure which should be made in liberal amounts. It is acid in reaction and should be limed for the best growth of all crops, particularly legumes. It is not high in phosphorus and phosphorus fertilizers would probably prove of value.

CALHOUN SILT LOAM (42)

The Calhoun silt loam is a very minor type in the county, covering 0.1 percent of the total area. It occurs in several small areas along Middle river, North river and the north fork of Clanton creek.

The surface soil of the Calhoun silt loam is a light brown to light brownish-gray floury silt loam 6 to 10 inches in depth. Below this point there is a layer of light gray to light yellowish-gray silt loam 8 to 10 inches in thickness. This passes abruptly into a heavy compact and impervious yellowish-gray silty clay to clay loam mottled with yellowish-brown in the lower depths.

In topography the Calhoun silt loam is nearly flat to gently undulating. It is poorly drained and the installation of tile is necessary to remove excess moisture. The type was originally forested with oak, but practically all of it has been cleared and is now in cultivation. General farm crops are grown and the yields are very much the same as on the Jackson silt loam. The type is in need of drainage particularly. It would respond to applications of farm manure, is acid in reaction and should be limed. It is not high in phosphorus and phosphorus fertilizers would probably prove of value.

SWAMP AND BOTTOMLAND SOILS

There are four swamp and bottomland soils in the county, all classified in the Wabash series. Together they cover 6.9 percent of the total area of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the largest individual bottomland soil, covering 3.3 percent of the total area of the county. It occurs along practically all of the

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more important streams in the county, the largest areas being found along North river and Clanton creek. These areas range from one-fourth to one-half mile in width. There are also well developed areas along South river in the southeast corner of the county, along Jones creek and Badger creek in the northeast corner and along Cedar creek. Narrow strips are found along the smaller streams in other parts of the county.

The surface soil of the Wabash silt loam is a dark brown to nearly black compact silt loam 4 to 20 inches in depth. Below this point it becomes a dark brown to black heavy silt loam to a depth of 24 to 28 inches where it changes to a heavy tough dark brown to grayish-brown silty clay to clay loam mottled with gray or yellowish-brown. There are many variations in the surface soil within the areas of this type. Along North river the surface soil is especially heavy and shallower than typical, passing from 8 to 14 inches into a tenacious impervious black silty clay to clay loam mottled with gray. Along North river the type is associated with the Wabash silty clay loam and the boundary lines are drawn more or less arbitrarily.

In topography the Wabash silt loam is generally level, sloping slightly toward the streams. The drainage is usually poor, particularly so where the subsoil is more impervious. The surface is 4 to 12 feet above the normal water level of the streams and much of the land is subject to overflow. The type is characteristically higher along the banks of the stream than it is back from the channel. Along the uplands the type is very rarely flooded.

Along the banks of the streams there are narrow belts of forest trees and these are principally oak, hickory, ash, cottonwood, willow and soft maple. About 85 percent of the type is under cultivation, corn being the most important crop grown. Oats, wheat and hay are also grown to some extent. Corn yields from 40 to 60 bushels per acre and under favorable seasonal conditions may

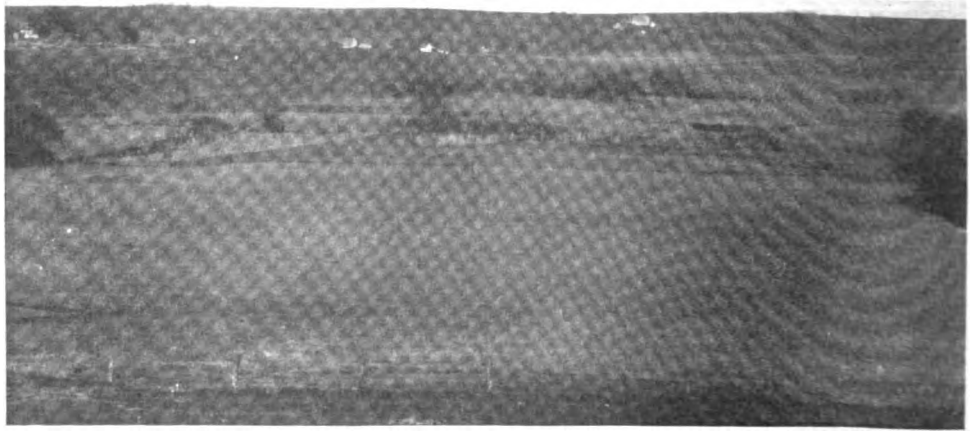

Fig. 8. Wabash silt loam occurs along Jones creek, with Lindley loam on the slope beyond.

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yield as high as 75 to 80 bushels per acre. Oats yield 30 to 60 bushels and wheat 18 to 35 bushels per acre. Hay crops generally yield 1 to 2 tons per acre.

The Wabash silt loam is in need of drainage to make it productive and also should be protected from overflow. When this is accomplished the type will permit of large crop yields. It is acid in reaction and will need lime when brought under intensive cultivation, especially for leguminous crops. Small applications of manure would be of value when the land is newly drained. Phosphorus fertilizers will be needed in the future and may prove of value in some cases at the present time.

WABASH FINE SANDY LOAM (62)

The Wabash fine sandy loam is a minor bottomland type covering 1.4 percent of the total area of the county. It occurs in numerous small areas along the streams of the county, being developed along Clanton creek, the tributaries of this stream in the southeastern part of the county, the West Branch of Grand river in the southwest corner of the county and along Middle river, North river and Jones creek. The largest individual area is found along Middle river south and west of Winterset.

The surface soil of the Wabash fine sandy loam is a brown to dark brown fine sandy loam 12 to 20 inches in depth. Below this point it becomes a brown to light brown fine sandy loam faintly mottled with gray. Below 30 inches the subsoil is a coarse light brown sand. Some gravel is found mixed with the soil thruout the three-foot section.

In topography the type is generally flat but owing to the loose open structure of the soil, drainage is good. It is subject to overflow regularly and hence varies considerably in character of surface material.

Only a part of this soil is under cultivation owing to the frequency of overflow. Corn is the most important crop grown and yields range from 35 to 40 bushels per acre. This soil should be protected from overflow if cultivated crops are to be grown successfully. When this is accomplished it would be benefited materially by the addition of organic matter. Liberal applications of farm manure would prove of value or leguminous crops might be used as green manures. The soil is usually acid and in need of lime for the best growth of legumes. It is not high in phosphorus and applications of phosphorus fertilizers will be needed in the future and may be of value in some cases at the present time.

WABASH LOAM (49)

The Wabash loam is a minor type in the county, covering 1.3 percent of the total area. It occurs chiefly along Grand river where it is found in narrow continuous strips covering practically all of the first bottom. Small areas are also found along Middle river, Clanton creek, North river and its tributaries.

The surface soil of the Wabash loam is a grayish-brown to dark brown mellow loam 8 to 12 inches in depth. Below this point it changes to a light brown to grayish-brown compact loam which passes at about 24 inches into a lighter brown fine sandy loam. The soil is quite variable because of the frequency of overflow. In some areas there is considerable sand and gravel in layers or pockets. There is a small area along Middle river, in sections 6 and 7

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of Scott township, where the soil is a light brown to brown loam 15 to 20 inches in depth, underlaid by a yellowish-brown fine sandy loam mottled with gray. The soil on this area really belongs in the Genesee series but was not mapped separately because of its small extent.

In topography the type is level and drainage is good. It is subject to frequent overflow, however, and there are a few poorly drained spots. Only a very small part of the soil is under cultivation and the land is used almost wholly as pasture. Much of it is forested, chiefly with cottonwood, willow, box elder, ash and post oak. If it is to be brought under cultivation the type would need to be protected from overflow, liberally supplied with manure and applications of phosphorus would probably be of value.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is a minor type in the county, covering 0.9 percent of the total area. It occurs along most of the larger streams of the county, the greater part being found along the North river. Small areas occur along Cedar creek and Clanton creek.

The surface soil of the Wabash silty clay loam is a black silty clay loam 8 to 10 inches in depth. Below this there is a black tenacious clay loam which changes at 18 to 20 inches into a dark brown to black stiff plastic clay loam mottled with dull brown or gray. Yellowish-brown mottlings and reddish-brown iron stains are found in the lower subsoil. This type is locally known as "gumbo" because of the sticky plastic character of the soil. Within the type there are included small areas of a mucky clay loam covered at a depth of 2 to 3 inches with a layer of decayed organic matter. These areas are found in depressions 5 to 100 feet in width and they remain marshy during most of the summer and support only a growth of reeds and coarse water grasses.

In topography the Wabash silty clay loam is level to flat. The drainage is poor and the type is subject to overflow. Most of it is uncultivated, growing only coarse fibered slough grass. In small areas which are under cultivation, corn, oats and hay are the principal crops. Where drainage is adequate corn may yield 40 to 65 bushels per acre. Oats produce fairly well but are likely to lodge.

If this soil is to be cultivated it is particularly in need of drainage. When this is accomplished and the type is protected from overflow, large crop yields may be secured. Small applications of farm manure might be of value on newly drained areas and applications of phosphorus will be needed in the future.

RESIDUAL SOILS

There are two residual soils in the county classified in the Sogn and Hagerstown series. Together they cover 3.1 percent of the total area of the county.

SOGN STONY SILT LOAM (155)

The Sogn stony silt loam is the larger of the residual soils but it is not very extensive in occurrence in the county, covering 2.9 percent of the total area. It is found along Middle river in the central and central western parts of the county, along North river, North Branch and Cedar creek in the northern part of the county and along Jones creek and upper Clanton creek in the south-

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Fig. 9. Limestone outcrops along the bluffs of Clanton creek west of Peru. In the distance is a limestone quarry.

eastern part of the county. The type is derived from the weatherings of narrow exposures of limestone and it occurs on steep slopes and in ravines.

The surface soil of the type is a black loose mellow silt loam 6 to 8 inches in depth. Here it passes abruptly into a grayish-brown to olive gray loam to clay which is tough, plastic and highly calcareous. It contains fragments of limestone and shale. The type is of little value for farming and can be used only for pasture. It supports a scant growth of hardwood trees. None of it is under cultivation.

HAGERSTOWN SILT LOAM (156)

The Hagerstown silt loam is a very minor type in the county, covering only 0.2 percent of the total area. It occurs in several small areas, the largest being found along Clanton creek northeast of East Peru, along Cedar creek northeast of Winterset and along North river north of Winterset. It also occurs in many areas which are too small to be shown on the map.

The surface soil of the Hagerstown silt loam is a light red to reddish-brown silt loam extending usually to a depth of 12 inches, averaging about 8 inches. In some places the surface soil has a purplish-red color and where it contains much organic matter the color is a dark reddish-brown. The subsoil is a reddish-brown stiff heavy clay loam to clay.

In topography the soil is sharply rolling and the type has little agricultural value. It occurs on the steep hillsides, being usually found midway up the hillside with the Sogn stony silt loam below. The type was originally covered by a sparse growth of hardwood trees. At present it is used mainly for pasture and woodlots.

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their

*Bulletin 150, Iowa Agricultural Experiment Station.

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food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the

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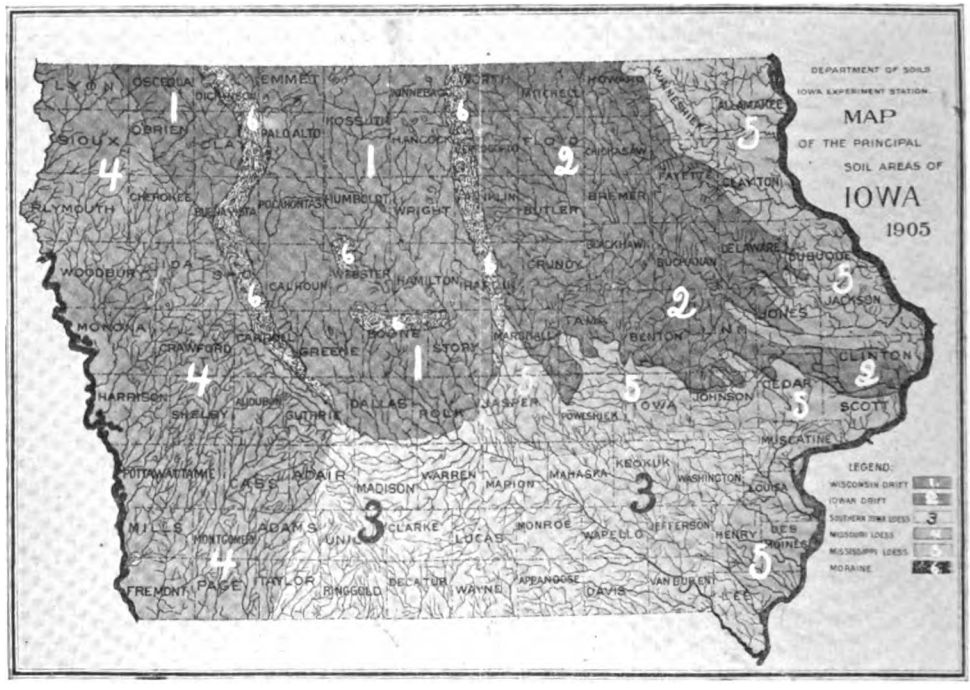

Fig. 10. Map showing the principal soil areas in Iowa

tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 10.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by

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differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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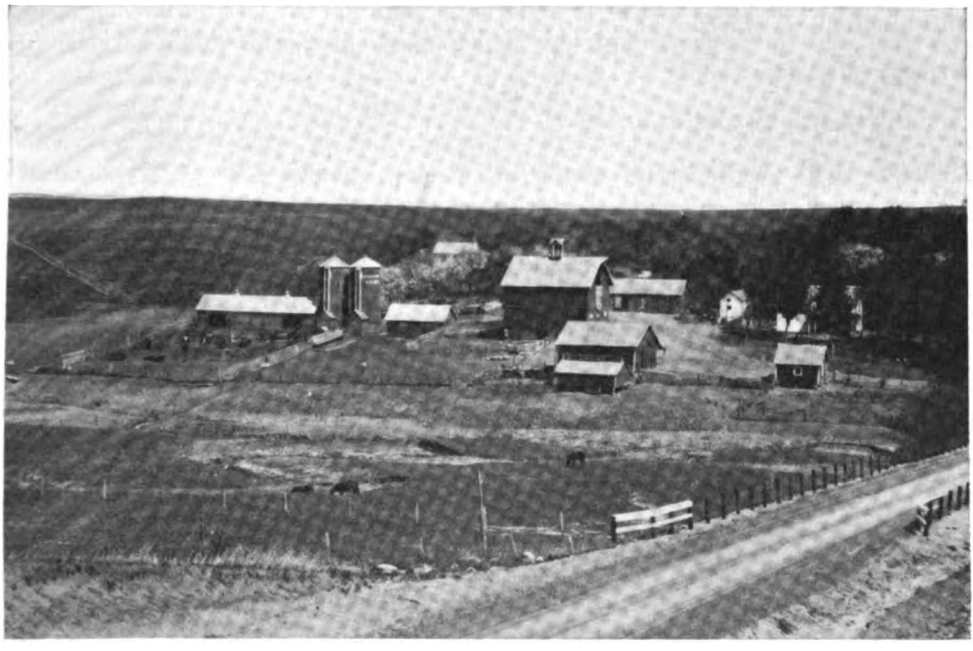
July, 1922 Soil Survey Report No. 27

SOIL SURVEY OF IOWA

Report No. 27—ADAIR COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman. T. H. Benton, and P. C. Wiechmann



A well-equipped farmstead in Adair county.

IOWA AGRICULTURAL
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C. F. Curtis, Director
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THE SOILS OF ADAIR COUNTY*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman, T. H. Benton, and P. C. Wiechmann

Adair county is located in southeastern Iowa, in the third tier of counties north of Missouri and the third tier east from the Nebraska line. It lies partly in the Southern Iowa loess soil area and partly in the Missouri loess. The soils of the county are largely loessial in origin, but in the Southern Iowa loess section a large part of the area is covered by a drift soil derived from the underlying drift formation, from which the thin covering of loess has been entirely removed.

The total area of Adair county is 573 square miles, or 366,720 acres. Of this area 349,897 acres or 95.4 percent is in farm land. The total number of farms is 2,132; the average size of the farms is 164 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land of the county:

Acreage in general farm crops	213,411
Acreage in pasture	112,340
Acreage in farm buildings, feedlots and public highways	16,204
Acreage in waste land	1,113
Acreage in crops not otherwise listed	222

The type of agriculture practiced in Adair county consists mainly of general farming and includes the raising of livestock and the production of some grains for market. The livestock industry is developing rapidly and includes principally the raising and feeding of beef cattle and hogs and to a less extent the raising of sheep, horses and mules. The crops grown are utilized mainly for feeding, but some of the grain produced, particularly the corn and wheat, is marketed. The livestock industry of the county may probably be considered of major importance, and the general farming practices which have been largely followed in the past are gradually changing to a livestock system.

There is a rather considerable area of waste land in the county, which may be very largely reclaimed thru proper methods of soil treatment. It is quite impossible to make general recommendations for the reclamation of waste land, owing to the fact that the causes of infertility are so variable. Special treatments which are needed for individual soil conditions are suggested in a later section of this report. Where the soil conditions are more or less abnormal, advice may be secured regarding the best method of handling the soil from the Soils Section of the Iowa Agricultural Experiment Station upon request.

The general farm crops grown in Adair county, in the order of their importance, are corn, oats, hay, wheat, barley, potatoes, rye and alfalfa. The average yields and value of these crops are given in table I.

Corn is the most important crop, both in acreage and value. One-third of the total area of the farm land in the county is devoted to this crop and average yields of 43 bushels per acre were secured in 1920. Both the yellow and white dent varieties are grown. Reid's Yellow Dent is the most popular yellow variety and Silvermine, Johnson County White and Boone County White are

*See Soil Survey of Adair County, Iowa, by Clarence Lounsbury of the U. S. Department of Agriculture and T. H. Benton and P. C. Wiechmann of the Iowa Agricultural Experiment Station.

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TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN ADAIR COUNTY, IOWA*

Crop	Acres	Percent of total farm land in the county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	117,700	33.6	43.0	5,061,000	$0.47	$2,378,670
Oats	49,300	14.0	39.0	1,922,700	0.36	682,172
Spring wheat	5,240	1.4	9.0	47,200	1.35	63,720
Winter wheat	4,500	1.2	18.0	81,000	1.41	114,210
Barley	8,280	2.3	27.0	223,560	0.63	141,842
Rye	650	0.1	12.0	7,800	1.17	9,126
Potatoes	781	0.2	79.0	61,699	1.22	75,272
Tame hay	22,050	6.3	1.4	30,870	16.24	501,328
Wild hay	4,770	1.3	2.0	9,540	12.69	121,062
Alfalfa	140	0.04	4.0	140	19.23	2,692
Pasture	112,340	32.1	....	.....	....	.....

the most commonly grown white varieties. A large part of the corn grown in the county is used on the farms for feeding purposes, but there is some sale of this crop out of the county. Some corn is grown for silage and utilized in this way for stock feeding.

The second crop in acreage and value in the county is oats. The value of this crop is very much less than that of the corn and it is grown on a much smaller total acreage. Average yields of oats amount to 39 bushels per acre. Iowa 103 and 105 are probably the most commonly grown varieties, tho some farmers prefer the Kherson variety. Practically all of the oats grown are utilized for feed on the farm and it is only very seldom that there is any surplus of this crop for sale on the outside markets.

Hay is the third crop of importance, there being a much larger acreage in the tame varieties than in wild hay. The total value of the tame hay and wild hay together is almost the same as the value of the oats grown in the county. Over 6 percent of the area of the county is utilized for hay, timothy and clover mixed being grown most commonly. Rather considerable areas are utilized for timothy alone and a much smaller area is seeded to clover alone. Average yields of tame hay amount to 1.4 tons per acre, while the average yield of the wild prairie grasses amounts to 2 tons per acre. Practically all of the hay produced in the county is fed on the farms.

Some wheat is grown, and the value of this crop is considerable. Both the spring varieties and the winter varieties are produced, the yields of the winter varieties, however, being very much better than those of the spring varieties. The total value of the winter wheat in 1920 was almost twice that of the spring wheat, altho the area was somewhat larger for the latter variety. Wheat is a cash crop and is mainly shipped out to the Chicago, St. Joseph or Kansas City markets.

Barley is a rather important crop, and average yields of 27 bushels per acre are secured. The value of this crop is considerable; in fact, it ranks next to wheat in importance. Some barley is sold, but the major portion of the crop is utilized for feeding purposes.

Rye is grown on a small area and is a relatively unimportant crop. Emmer and buckwheat are crops of minor importance, and there are small acreages

*Iowa Yearbook of Agriculture, 1920.

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devoted to millet and alfalfa. The latter crop is becoming more popular as more is learned regarding the methods to be followed in seeding and harvesting. Average yields of this crop amount to 4 tons per acre and it makes a valuable feed. When the soil is put in a satisfactory physical condition and good seed is used, a satisfactory stand of alfalfa should be secured.

Potatoes are grown rather extensively in the county, chiefly to supply the home demand. Average yields of 79 bushels per acre are secured. Some sorghum is grown and utilized both for syrup and for forage. In the year of the survey, a rather large acreage was devoted to sugar beets.

There are no commercial orchards in the county, but practically every farmer maintains an apple orchard and produces enough fruit to supply the home demand, with occasionally a small surplus. The orchards are not generally cared for as well as they should be, and where pruning and spraying are practiced, the yields of apples are very much larger. There are some peach, plum and cherry trees on the farms and various small fruits are grown. These are all utilized to supply the home demand.

THE LIVESTOCK INDUSTRY OF THE COUNTY

The livestock industries of the county include the raising and feeding of cattle, hogs and sheep and the raising of horses and mules. Some dairying is practiced, also. The following figures, taken from the Iowa Yearbook of Agriculture for 1920, show the extent of the livestock industry of the county:

Horses, all ages	13,864
Mules, all ages	1,279
Swine, on farms July 1, 1920	99,796
Swine, on farms Jan. 1, 1921	80,816
Cattle, (cows and heifers, kept for milk)	8,597
Cattle, (other cattle not kept for milk)	35,832
Cattle, (all ages Jan. 1, 1921)	44,429
Sheep, (all ages on farms Jan. 1, 1921)	16,084
Sheep, (shipped in for feeding 1920)	2,906
Sheep, (total pounds of wool clipped)	110,054
Poultry, (total all varieties Jan. 1, 1921)	274,914
Poultry, (number dozen eggs received 1920)	1,054,297

Beef cattle raising and feeding is one of the most important of the livestock industries, most of the cattle being raised in the county, but some feeders are shipped in for finishing. Of the various breeds, the Shorthorns seem to be the most popular. There are also some herds of Hereford or Aberdeen Angus and a few grade Jerseys and Holsteins. Herds range in size from 25 or 30 on the average farm to 100 or more on larger farms.

Dairying is practiced to some extent in the county and most farmers keep some milk cows, chiefly Shorthorns. The value of the dairy products is considerable. Besides supplying the home demand, the products are sold to the creameries and out of the county. There is a creamery at Greenfield and others at Adair and at Menlo in Guthrie county. Much of the butter produced at the Greenfield creamery is shipped to New York.

The raising and fattening of hogs is a general practice in the county and practically every farmer raises some hogs and in many instances the swine industry is the most important. The Poland China breed is the most popular, but the Duroc Jersey and Chester White breeds are also favored. Many of the hogs are purebred and the remainder are largely very good grades.

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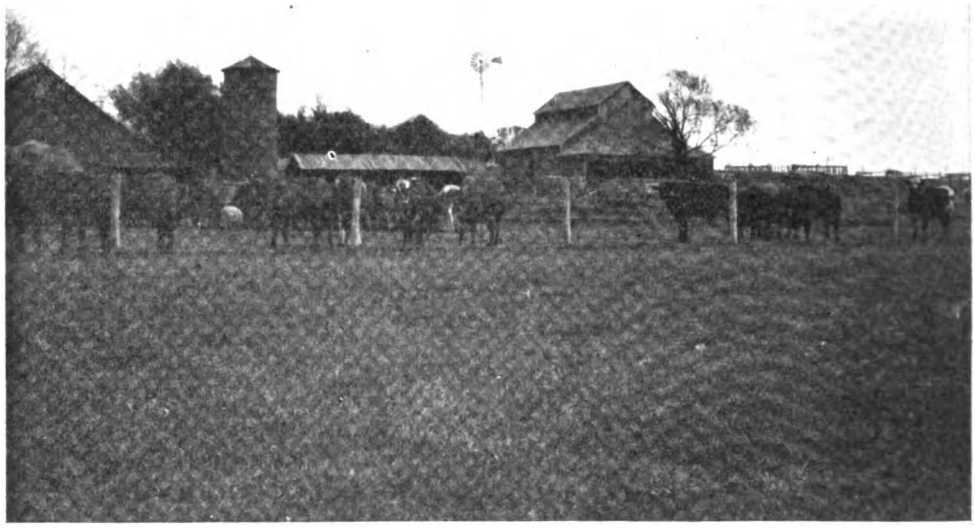

Fig. 1. An Adair county feedlot. Beef cattle raising and feeding is an important industry.

Sheep are raised quite generally in the southeastern and western parts of the county. The Shropshire is the most popular breed. The value of the wool produced in 1920 was considerable, as will be evident from a consideration of the figures given in the table showing the total pounds of wool clipped. Some horses are raised in the county, altho only a few make a specialty of breeding horses. Practically every farmer raises a few colts or mules each year. Poultry is raised on all farms and the poultry products are very largely disposed of at the local markets. The value of the poultry products is very large and they add considerably to the income on the farms.

The value of land in Adair county is quite variable, depending upon the location with reference to towns and railroad facilities, the improvements on the farms and the general soil conditions. The price of the farm land ranges from $150 to $400 per acre. In some instances even higher prices have been secured. The average price, however, for the farm land of the county would be about $250 per acre. Improved land on the Tama silt loam will average about $300 per acre, while in the more rolling sections less well adapted for cultivation, as, for example, in areas of the Shelby loam and on the Wabash soils, the price will range from $150 to $250 per acre.

The yields of general farm crops grown in Adair county are usually quite satisfactory, but in many instances proper methods of soil treatment would undoubtedly result in the securing of larger crops. The treatments which should be practiced will vary on the different soils of the county, depending upon the particular conditions and upon the characteristics of the individual types, particularly the topographic features.

In some instances the drainage conditions are not entirely satisfactory and, when this is true, the first treatment needed to bring about satisfactory crop yields will be the installation of tile drains in soils which are too wet. No

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matter if the cost of the installation of tile is considerable, the expense will be more than warranted by the results secured in the way of larger crop yields.

The soils of the county are all acid in reaction and the application of lime is necessary in all cases in order to secure the best growth of general farm crops, and particularly of legumes. The acidity of the surface soil persists in most cases thruout the subsoil. Only in two instances is there any inorganic carbon in the lower subsoil and in both these cases the amount present is so small that there would be no effect on the needs of the surface soil. It is evident that all the soils of the county should be tested for lime requirement and lime should be applied as shown to be necessary, if crop growth is to be entirely satisfactory. There is considerable experimental evidence and some farm experience showing the beneficial effect of lime when applied to acid soils and showing, also, the large effects of the material in the case of legumes.

Most of the soils of the county are not particularly well supplied with organic matter and the application of farm manure is particularly desirable in order to put the soils in better condition for crop growth. This material brings about large increases in crop yields and is undoubtedly the most valuable fertilizing material which can be used in the county. If farm manure is not available, leguminous crops may be used as green manures and thus serve to keep up the supply of organic matter. Such crops also supply nitrogen to the soil and hence have a double value. It is very necessary that the nitrogen content be kept up in the soils of the county, and in some instances the addition of nitrogenous materials would undoubtedly prove of value. The use of leguminous crops as green manures may, therefore, be very desirable on many of the soils of this county.

The phosphorus supply is low in practically all of the types, and it seems probable that phosphorus fertilizers would prove profitable in many cases. Applications of these materials to small areas are recommended in order that information may be secured regarding their value under individual farm conditions. If profitable increases are secured in such tests, applications may be made to large areas with the assurance of profit.

Complete commercial fertilizers cannot be recommended at the present time for general use in the county, as it is believed that the phosphorus fertilizers will prove quite as satisfactory and less expensive. Such materials may be tested, however, by any farmer who is interested in determining their value. If they prove valuable in increasing crop yields to a profitable extent and particularly if they bring about a more profitable increase than a phosphorus fertilizer, then they may be applied to large areas without fear of injuring the soil.

Erosion occurs to some extent in Adair county and it is very desirable that some method of preventing the washing away of the surface soil should be adopted wherever this injurious action occurs. The formation of gullies occurs to some extent in the rougher uplands and unless these are checked, considerable areas may be rendered useless agriculturally. The carrying away of the surface soil by sheet erosion, while less apparent, is quite as injurious, and unless proper methods are followed to check the action, crop yields will be reduced, owing to the formation of shallow soil conditions. Any expense in-

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volved in the prevention of erosion is well warranted by the better results secured from crops grown and by the continued fertility of the soil.

THE GEOLOGY OF ADAIR COUNTY

The original bedrock material underlying the soils of Adair county has been buried so deeply under the glacial deposits of succeeding geological ages that it exerts no effect upon the soil conditions. Only in a few places in the county is there any exposure of this underlying rock. This material appears mostly along the right bank of Middle river.

At least once during the glacial age, a great glacier swept over this county and, on its retreat, left behind a vast amount of glacial drift or till. This glacier is known as the Kansan. The drift which it left behind has a thickness estimated at 200 feet, over practically all of the county. The earlier topographic features of the county were very largely obliterated by the glacier upon its advance and hence the depth of the drift deposit is more or less uniform, but there are some places where the deposit is deeper, indicating the location of earlier topographic depressions which were filled by the glacial deposit.

This Kansan drift material is blue in its natural, unoxidized condition, but where it has been exposed to the air, it has changed to a bright yellow or deep reddish-brown. Pockets of sand and gravel occur and boulders are frequently found thruout the drift deposit. The topographic features of the county at the present time are largely the result of weathering and washing of this drift deposit, and apparently the topography was little modified by the later glacial deposit.

The Shelby loam, one of the largest soil types in the county, is derived from the Kansan drift deposit, and the surface soil of this type has been produced thru weathering and the accumulation of organic matter in the Kansan drift. The color of the surface soil has been changed to a dark brown to almost black, but the subsoil is typical of the oxidized Kansan till, being a yellow or reddish-brown. The Lindley loam, a minor type in the county, is also derived in large part from the Kansan drift, the surface soil of the type being partly composed of loess. This type is really a mixture of loess and drift, with the latter predominating, particularly in the subsurface and subsoil layers.

Overlying the glacial deposit, there was laid down, at some time when climatic conditions were very different than at present, a layer of silty material known as loess. The deposition of this material was probably brought about by wind action and probably the entire surface of the county was covered. Since the deposit was made, however, much of the loess has been washed away from the slopes and the underlying glacial drift has been exposed. The areas of Shelby loam which have been mentioned represent that part of the county where the loess has been entirely removed, while the areas of Lindley loam indicate the stage of partial removal of the loess covering. Where the loessial material has not been removed by erosion, the soils of the Tama, Clinton and Grundy series are mapped.

Loess in its unweathered condition is an even-grained material composed largely of silt. It ranges in color from light grayish-brown to yellow-brown.

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Due to weathering and the addition of organic matter, the soils formed from the loess are very largely dark in color and, where there has been abundant plant growth and accumulation of vegetable matter under prairie conditions, the soils are quite black in color, as, for example, where they are mapped in the Tama and Grundy series. Where the loess has weathered under forested conditions, organic matter has not accumulated to such a large extent and the soil is gray to light brown, as is the case in the types in the Clinton series. Under the wooded conditions the loess has been washed away to a larger extent, more leaching has occurred and the soil is somewhat poorer in fertility. In all cases the lime has been removed from these loess soils by leaching and they are acid in reaction.

There is a distinct relation between the topographic features of the soil types and the fertility conditions. Thus, the more level soils of the Tama and Grundy series are much richer and more fertile than the Clinton series. The rolling to steep areas of the drift soils are poorer in fertility than even the less productive loess types.

The terrace and bottomland soils of the county are derived very largely from the loess of the upland, altho there is some admixture with the drift from the uplands. Both of these materials are washed down by the rains and deposited in the bottoms, leading to the formation of the Wabash soils, the lighter textured types representing the loessial deposit, while the heavier types are apparently modified by an admixture of drift material.

PHYSIOGRAPHY AND DRAINAGE

In topography Adair county varies from fairly level to strongly rolling, to steep. The larger portion of the county, however, is moderately rolling in topography, and the surface of the loessial area, in particular, is a succession of smoothly rounded hills, sloping gradually to the more level bottomlands. The land in the county slopes either toward the east and southeast or toward the southwest, the area in the entire eastern portion of the county draining into the Des Moines river, while the western portion of the county drains into the Missouri river. The higher land in the county, representing the divide between the tributaries to these two large streams, extends across the county from the northwestern corner near Adair, in a southeasterly direction, almost to the center of the county, then east into Madison county between Middle river and Grand river. A branch of this divide also extends southward from the center of the county, thru Greenfield, to the Union county line.

Northeast of Middle river the topography is less strongly rolling and there are considerable areas of rather level land southeast of Stuart, which are mapped in the Grundy series. The Shelby loam, which borders many of the streams thruout the county, separating the bottomland soils from the rolling Tama of the upland, is frequently rather rough in topography and the slopes to the bottoms may sometimes be very steep. This topographic condition seems to occur more generally along the south sides of eastward and westward flowing streams. Many of the Shelby loam areas are moderately rolling and the slope from the Tama uplands to the Wabash bottoms is usually quite gradual. There are some areas of Lindley loam in the county where the topography is quite

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rough to rolling, and there is some occurrence of the Clinton silt loam, along the eastern boundary of the county, where the topography is strongly rolling. Some areas of the Shelby loam, the Lindley loam and the Clinton silt loam are too steep for agricultural utilization, but in the main the soils of the county are not topographically unfit for general agricultural use. Erosion occurs to considerable extent in the more rolling areas and the general topographic conditions in the county indicate that some methods must be employed for the prevention or control of destructive erosion, or the washing away of the surface soil.

The bottomlands of the county are rather extensive in total area, but occur only in narrow strips along the various streams and drainageways, and they are level in topography, poorly drained and subject to overflow.

The drainage of the county is brought about mainly by the Middle Nodaway river and its tributaries, and Grand river, Middle river, and North river, with their tributaries. The West Fork Nodaway river is the most important tributary of the Middle Nodaway and, together with Rut Branch and Nine Mile

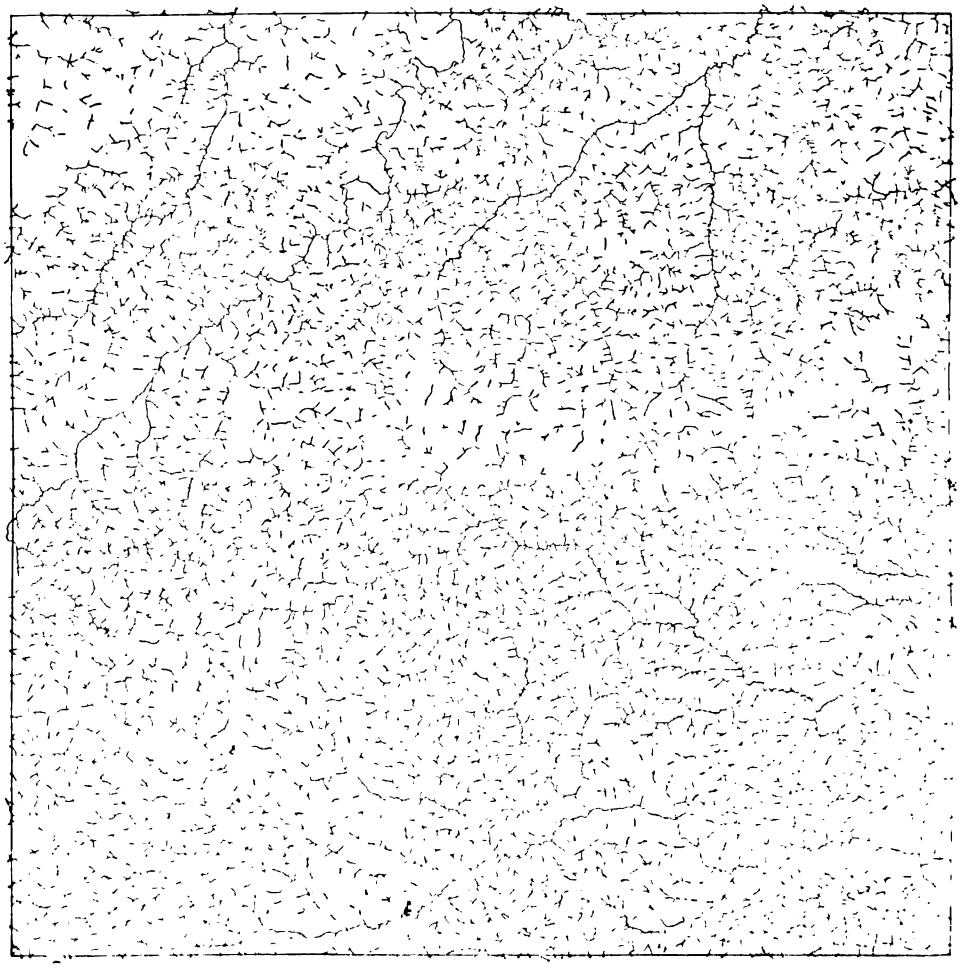

Fig. 2. Map showing natural drainage system of Adair county.

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creek, it drains most of the western part of the county. The Middle Nodaway, with its small tributaries, drains the central western part of the county. Shanghai creek and the East Branch Nodaway river and Three-Mile creek drain the southern part of the county. The more important tributaries of the Grand river are Nine-Mile creek, Marvel creek, and Battle creek. Turkey creek and Bruce Branch are the main tributaries of the Middle river. These rivers and their tributaries, together with Grassy Run, bring about the drainage of the entire eastern part of the county, including much of the northern part. The area around Adair drains north thru a branch of the Middle river into Guthrie county. These various streams, with their tributaries, extend to practically all parts of the county. Only in a few small areas is there inadequate drainage, most of the soils being well drained. The areas of Grundy silt loam in the northeastern part of the county are poorly drained, and this is the only soil type which is naturally in need of tiling. There are some instances, however, where the drainage is not entirely satisfactory on some of the other upland types. The Wabash clay loam of the bottoms is poorly drained, also, and the bottomland soils are all subject to overflow. In general, artificial drainage should not be needed to any extent in the county and the installation of a small amount of tile would undoubtedly take care of minor areas where the drainage is inadequate. The accompanying map indicates the extensive drainage system of Adair county and shows that all the soils of the county may be readily drained into the major streams and their tributaries.

THE SOILS OF ADAIR COUNTY

The soils of Adair county are grouped into four classes, according to their origin and location. These are drift soils, loess soils, terrace soils, and swamp and bottomland soils.

Drift soils are formed from the materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They are variable in composition and may contain pebbles and boulders. Loess soils are fine, dust-like deposits made by the wind at some geologic time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them, or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low, poorly drained areas, or along streams, and they are subject to more or less frequent overflow. The extent and occurrence of these groups of soils in Adair county are shown in table II.

Over one-half of the total area of the county is covered by the loess soils, 51.6 percent being occupied by the various types in this group. The drift soils

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN ADAIR COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	138,944	37.9
Loess soils	188,800	51.6
Terrace soils	1,984	0.5
Swamp and bottomland soils	36,992	10.0
Total	366,720	....

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are also extensive, covering somewhat over one-third of the total area of the county, 37.9 percent. There is a relatively small area in terrace in the county and only one terrace type. This soil covers only 0.5 percent of the total area of the county. Swamp and bottomland soils are much more extensive than the terrace types and together they cover 10.0 percent of the county.

There are eight individual soil types in the county and these, together with the shallow phase of the Tama silt loam, make a total of nine separate soil areas. There are two drift soils, four loess types, including the phase of the Tama just mentioned, one terrace soil and two swamp and bottomland types. These various soil types are distinguished on the basis of certain soil characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Tama silt loam is the largest individual soil type in the county, covering over one-third of the total area in its typical development. Together with the shallow phase of the type, slightly over one-half of the total area is included in this type. The Shelby loam is the second largest soil type in the county, and the largest drift soil. It covers a slightly smaller area than the typical Tama silt loam, occupying slightly over one-third of the total area of the county, 36.4 percent. The Wabash loam is the most extensive bottomland type and is the third largest type in the county, covering 8.4 percent of the total area. The Wabash clay loam is second in area to the Wabash loam, covering 1.6 percent of the county. The Lindley loam is the second drift type, and is minor in area compared with the Shelby loam. It covers 1.5 percent of the total area of the county. The Clinton silt loam and the Grundy silt loam, the remaining loess types in the county, are both minor in area, covering 0.7 and 0.5 percent. The Judson silt loam, the only terrace type in the county, is minor in area, covering 0.5 percent.

The topography of the uplands of the county varies considerably, depending upon the particular soil type which occurs on them. The Tama silt loam and its shallow phase both occur under gently rolling topographic conditions. The Shelby loam is found under more strongly rolling to steep topographic conditions and, in some areas, the type is found in a rough, broken topography.

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN ADAIR COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
79	Shelby loam	133,312	36.4
65	Lindley loam	5,632	1.5
	LOESS SOILS		
120	Tama silt loam	136,832	50.4
143	Tama silt loam (shallow phase)	47,872	
80	Clinton silt loam	2,432	0.7
64	Grundy silt loam	1,664	0.5
	TERRACE SOIL		
131	Judson silt loam	1,984	0.5
	SWAMP AND BOTTOMLAND SOILS		
49	Wabash loam	30,976	8.4
63	Wabash clay loam	6,016	1.6
	Total	366,720	—

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The Lindley loam is very similar topographically to the Shelby loam and may be strongly rolling to steep in topography. The Clinton silt loam ranges from gently rolling to strongly rolling and in some areas is rather steep. The Grundy silt loam is a more level to very slightly undulating type and it is on the areas of this soil that drainage is sometimes inadequate. The remainder of the upland soils of the county are generally quite adequately drained. The terrace and bottomland types all have a level topographic position and in the case of the Wabash soils on the bottoms, not only is drainage needed to make them productive, but they must be protected from overflow if the best crop yields are to be secured.

THE FERTILITY IN ADAIR COUNTY SOILS

Samples were taken for analyses from each of the soil types in Adair county. The more extensive types were sampled in triplicate, but only one sample was taken in the case of the minor types. All samplings were made with the greatest of care that the samples should represent the particular soil types and that variations due to local conditions and previous treatments should be eliminated. Samples were drawn at three depths, 0—6 2/3", 6 2/3"—20" and 20"—40", representing the surface soils, the subsurface soils and the subsoils, respectively. Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon, and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods and the Truog qualitative test was used for the limestone requirement tests. The figures given in the tables are the averages of duplicate determinations on all samples of each type and they represent, therefore, the averages of four to twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre. The phosphorus content of the soils of the county is somewhat variable, ranging from 880 pounds, in the case of the Shelby loam, up to 1,320 pounds in the

TABLE IV. PLANT FOOD IN ADAIR COUNTY, IOWA, SOILS

Pounds per acre of 2,000,000 pounds of surface soil per acre (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem't
	DRIFT SOILS					
79	Shelby loam	880	2,720	33,108	0	3,333
65	Lindley loam	970	2,680	33,742	0	5,000
	LOESS SOILS					
120	Tama silt loam	1,270	4,130	52,998	0	6,000
143	Tama silt loam (shallow phase)	1,104	3,460	40,567	0	6,000
80	Clinton silt loam	916	2,280	26,644	0	4,000
64	Grundy silt loam	1,158	4,420	58,149	0	5,000
	TERRACE SOIL					
131	Judson silt loam	1,212	3,460	39,659	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,064	3,800	46,137	0	2,000
63	Wabash clay loam	1,320	3,740	47,611	0	2,000

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case of the Wabash clay loam. There is no apparent relation between the phosphorus content of the soils in the various soil groups. The terrace soil is somewhat higher than the average of the other groups, and the bottomland types average somewhat higher than the upland soils, but there are so few types within each group that definite comparisons should not be made. Variations within groups are even larger than those between the various groups.

It is hardly possible from the analyses of these soils to draw any conclusions regarding the relation between the soil series and texture and the phosphorus supply. There are too few soil types represented in the county and only in one case are there soils in the same series of different textures. It might be noted, however, that the Grundy silt loam and the Tama silt loam are much better supplied with plant food in general than the Clinton soil of the same texture. The Tama silt loam and the Grundy are very much alike, as is generally the case. There is very little difference in the Lindley and Shelby loams, but these are poorer in plant food than the loess soils, which may be due in part to the series in which they occur and in part to the texture. Silt loams would ordinarily be expected to prove somewhat richer than loams.

There is undoubtedly some relation between plant food content and soil series, because of topographic differences. Thus, the Grundy silt loam is richer than the Clinton, because of its topography; at least, this may be partly the reason for the larger amount of plant food. A further reason is that the Grundy has been developed under prairie conditions, while the Clinton has been developed under wooded conditions. The shallow phase of the Tama is, of course, lower in plant food than the typical Tama, as would be expected, owing to the fact that it has been formed by the washing away of much of the surface soil. The two soils of the Wabash series differ somewhat in plant food, particularly from the phosphorus standpoint. The clay loam is higher than the loam in this constituent, which is a direct result of different textural conditions. It might be expected that the bottomland types would be somewhat higher than the upland soils, owing to their level topographic position and to the fact that crop production has been less on these types in the past and there has been less removal of plant food. Similarly, it might be expected that the Grundy silt loam would be higher than the Clinton silt loam in this constituent. The differences between the supply in the loess soils and the drift types may go back to the origin of the soils, altho the origin is probably secondary in consideration to the conditions to which the soils have been subjected since their formation.

In general, it is apparent from these analyses that there is no large supply of phosphorus in the soils of Adair county, and phosphorus fertilizers will certainly be needed on these soils in the near future if satisfactory crop yields are to be secured. It is quite possible, however, that phosphorus carriers will prove of considerable value at the present time on many of the soils, and such materials must certainly be taken into account in planning systems of permanent fertility for the county.

It should be emphasized that the total supply of phosphorus in the soils does not show how much of this element is available for the use of crops, and the figures given in the tables merely serve to indicate the store of this element

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which may be drawn upon more or less rapidly, depending upon the soil conditions which affect the production of available plant food. It is generally conceded, however, that when the total supply of any plant food constituent reaches a low figure there will be a very small production of that element in an available form. In other words, the reduction in total content of phosphorus will mean a very much more rapid reduction in the production of available phosphorus; hence, when the total supply of this element in the soil is low, it is almost certain that crops will not secure sufficient phosphorus in an available form to bring about the best growth. But even when the total amount of phosphorus is considerable, the supply of available phosphorus may be lacking if the soil conditions are not such that there is a rapid transformation of unavailable to available phosphorus.

It is quite reasonable, therefore, to conclude from the analyses given that phosphorus fertilizers may prove of value on many of the soils of the county at the present time, and especially on those types which seem to be rather low in this constituent. Furthermore, the same fertilizers may prove of value on the soils which are better supplied with phosphorus and in no case is the amount of phosphorus sufficient to keep crops supplied for any extended period, even if it were all made available as rapidly as it could be utilized. Farmers are urged to test the use of phosphorus fertilizers on their own soils and thus determine for their own particular farm conditions the need of phosphorus, and which phosphorus fertilizer should be applied, whether rock phosphate or acid phosphate. Such tests should be carried out on a small area and if profitable crop increases are secured, then the same materials may be applied to larger areas with the assurance of profit.

The nitrogen content of the soils of the county is quite as variable as the phosphorus supply, ranging from 2,280 pounds, in the Clinton silt loam, up to 4,420 pounds in the Grundy silt loam. There is no relation between the nitrogen content of the various types and the different soil groups, and no comparisons can be made, owing to the small number of soil types and the small differences which occur. Neither is it possible to draw any conclusions regarding the relation between the soil series and the soil textures from the nitrogen standpoint. The Grundy and Tama soils are, however, higher in nitrogen than the Clinton soils and they are likewise higher than the Shelby and Lindley soils of the drift upland. This difference is very largely due to the conditions under which these soils have been formed, and is indicated also, by the color of the soil. There may be some effect of the texture, also, but if so, such effects cannot be noted in the comparisons which can be made. There is very little difference between the clay loam and the loam in the Wabash series, the only place where an actual textural comparison can be made.

While the soils of this county seem to be in general fairly well supplied with nitrogen, there is no large amount present in any case and this element will certainly need to be considered in planning systems of permanent fertility for the county. Some nitrogenous fertilizing material must undoubtedly be used at regular intervals on these soils if the nitrogen supply is to be kept up.

Farm manure is a very important nitrogenous fertilizer, returning to the soil, as it does, considerable amounts of nitrogen which have been removed

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by the various crops utilized in the feed. The proper utilization of crop residues aids in keeping up the nitrogen supply in the soil and these materials should always be very carefully utilized.

On many livestock farms, where the supply of manure is insufficient to provide for all the soils, and on the grain farm, where manure is lacking, the nitrogen content of the soil should be increased and kept up by turning under well inoculated leguminous crops as green manures. When such crops are well inoculated, they draw a large portion of their nitrogen from the atmosphere, and when turned under in the soil, they serve as nitrogenous fertilizers. The actual amount of nitrogen supplied to soils by this means will vary to a considerable extent, depending upon the thoroness of the inoculation of the legume, the amount of crop growth secured, and the amount turned under in the soil. Many legumes may be used as green manures to serve as nitrogenous fertilizers and such materials are undoubtedly the cheapest and most satisfactory source of nitrogen which can be employed.

The organic carbon content of soils is a measure of the organic matter contained in them and the amount of this constituent present is indicated quite definitely by the color of the soil. Furthermore, there is a very close relation between the organic carbon and the nitrogen in soils and hence a relation of nitrogen to color. If the soil is black in color, the amount of organic carbon and nitrogen present will be high. If the soil is light in color, there is undoubtedly a deficiency in these constituents.

Most of the soils of Adair county are fairly well supplied with organic carbon, as is indicated by their typical dark brown to black color. There are a few cases, however, where the amount of organic matter is rather low, for example, in the Clinton, Shelby and Lindley soils. The amount of organic carbon ranges from 26,644 pounds, in the Clinton silt loam, up to 58,149 pounds in the Grundy silt loam. It is apparent that the relations mentioned in the case of nitrogen very largely hold true for the organic carbon, and the more level upland loess soils developed under prairie conditions are richer in organic carbon than the more rolling types developed under wooded conditions. It is hardly possible from the results given in the table to draw any conclusions regarding the relations between organic carbon and nitrogen and the texture of the soil, owing to the fact that so few soils of the same series and of different texture are found in the county.

The relation between the carbon and nitrogen in soils gives rather definite evidence of the rate at which plant food is being made available. It would seem that in this county the relation between these constituents should be such that a satisfactorily rapid production of available plant food would occur. There are several instances, however, where the relation between these constituents might be improved thru the addition of organic matter, and where the production of available plant food should take place more rapidly. The fact that applications of manure prove of so much value on most of these soils is an indication of the fact that the production of available plant food might be stimulated with profitable effects on crop yields. This is evidently the cause, in part, at least, of the beneficial effect of applications of manure, but there are other factors involved, of course, one of the most important being the

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addition of bacteria, the result of which is an increased production of available plant food. It is usually conceded that on soils fairly well supplied with organic matter, the value of manure may be due in large part to the introduction of bacteria and the stimulation of bacterial action.

The maintenance of the organic matter content of the soils of the county is of considerable importance, and the utilization of farm manure for this purpose is most desirable. Crop residues should also be utilized to aid in keeping up the supply of organic matter, and the growing of legumes and turning under of part or all of the crop is a further method of supplying organic matter to the soil. On grain farms where farm manure is not available, leguminous green manure crops should be used as substitutes for that material in order to keep up the supply of organic matter.

There is no inorganic carbon in any of the soils of the county, and they all show a limestone requirement according to the qualitative Truog test. There is some variation in the acidity in the various soil types, but the figures given in the table should be considered merely indicative of the needs of the various soil types. As soils vary widely in lime requirements, different tests of the same type, even from the same field, may show rather wide variations. It is quite evident that the soils of this county should all be tested for acidity.

Legumes will not grow satisfactorily on acid soils and the application of lime may mean the difference between a profitable legume crop and failure of the crop. The effect of lime will show on the succeeding grain crops of the rotation and, in general, the beneficial effects of liming are apparent on all crops of the rotation, but are particularly evident on legumes. The soils of this county should be tested at the present time and tests will also be needed in the future in order to keep up the supply of this constituent. It is usually suggested that the soils be tested once in four years and lime applied preceding the legume crop of the rotation. Farmers of Adair county will need to see to it that lime is applied to their soils now as needed, and also at regular intervals in the future, if they are to secure satisfactory crop yields and keep their soils permanently productive.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface and 6,000,000 pounds of subsoil per acre. The amount of plant food present in the lower soil layers has little effect upon the fertility of the surface soil, unless there is a large content of some particular element. None of the soils in Adair county seem to have any large supply of plant food in the lower layers and hence it is hardly necessary to consider these results in detail.

The results of the analyses of the surface soils seem to indicate quite definitely the needs of the soils of the county and the conclusions which were drawn from these analyses are not modified to any extent by a consideration of the plant food present in the lower soil layers. The phosphorus content of the soils is low thruout the 3-foot section and there is need for the addition of phosphorus fertilizers, if these soils are to be kept supplied with this constituent. In all probability phosphorus fertilizers would prove of value on many of the soils

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TABLE V. PLANT FOOD IN ADAIR COUNTY, IOWA, SOILS
Pounds per acre of 4,000,000 pounds of subsurface soil per acre (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	1,500	3,213	39,572	0	3,333
65	Lindley loam	2,290	1,760	19,656	0	3,000
	LOESS SOILS					
120	Tama silt loam	1,590	6,560	78,878	0	6,000
143	Tama silt loam (shallow phase)	916	3,920	47,283	0	4,000
80	Clinton silt loam	1,482	2,800	31,122	0	5,000
64	Grundy silt loam	1,454	4,560	63,882	0	4,000
	TERRACE SOIL					
131	Judson silt loam	2,182	5,600	63,663	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,886	6,600	84,630	0	2,000
63	Wabash clay loam	2,614	8,600	127,218	0	2,000

in the county at the present time, and tests of these materials are to be recommended. The supply of nitrogen is not high and materials supplying nitrogen should be added to these soils at regular intervals. The organic matter content must also be kept up and the use of farm manure and leguminous green manures will maintain the supply both of nitrogen and of organic matter. The application of manure to these soils is particularly desirable and will bring about large effects on crop yields.

The soils are all acid in reaction and applications of lime are necessary in order to put the soils in the best condition for the growth of all crops and particularly for the satisfactory growth of legumes. It is very important that every soil in the county be tested for acidity and that lime be applied, as necessary, before a legume is grown. The amount of lime which is needed on the soils of the county will be determined very largely by the tests of the surface soils. The fact that the lower soil layers are also acid means that it will be necessary to apply lime at regular intervals in the future in order to bring about a complete neutralization of all acidity thru the soil section. The addition of sufficient lime to take care of the acidity in the surface layer will, however, be sufficient for the satisfactory growth of legumes at the present time.

TABLE VI. PLANT FOOD IN ADAIR COUNTY, IOWA, SOILS
Pounds per acre of 6,000,000 pounds of subsoil per acre (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
79	Shelby loam	2,451	3,160	36,031	10,300	Basic
65	Lindley loam	2,829	3,480	40,950	0	5,000
	LOESS SOILS					
120	Tama silt loam	2,061	5,460	60,879	0	6,000
143	Tama silt loam (shallow phase)	807	2,820	32,760	0	3,000
80	Clinton silt loam	3,393	2,820	32,760	0	5,000
64	Grundy silt loam	2,910	4,200	52,416	0	2,000
	TERRACE SOIL					
131	Judson silt loam	2,787	4,200	46,683	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	2,667	12,240	24,570	0	3,000
63	Wabash clay loam	2,787	8,400	136,853	1,230	Basic

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GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Adair county in the attempt to learn something of the fertilizer needs of the soils of the county and to secure indications of the value of certain fertilizer materials. These experiments were carried out on the Tama silt loam and the Shelby loam, the two major soil types in the county. The results of experiments on the Tama silt loam in Cedar and Marshall counties and on the Shelby loam in Wayne county are also included, inasmuch as the types are the same as the main types in Adair county and the results very largely confirm those secured in the experiments on the same soil types from Adair county.

The treatments used in all of these experiments included the application of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The amounts of these materials used were the same as those employed in the field tests and hence the results of these greenhouse experiments may be considered to indicate rather definitely the results which may be secured in the field. Manure was applied at the rate of 8 tons per acre, lime was added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional, rock phosphate was added at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of complete commercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the various experiments, the clover being seeded about one month after the wheat was up. In several cases the clover yields only are given in the tables, as the wheat yields were not secured.

The green weights of clover on the Shelby loam from Adair county are given in table VII, the figures being the averages of the yields on the duplicate pots. The application of manure brought about a very large increase in the yield of clover, and apparently this material is an extremely valuable fertilizer on this soil. The addition of lime along with manure increased the clover yield to some extent, as might be expected, as this soil is uniformly acid in reaction and in need of lime for the best growth of legumes. The addition of phosphate fertilizers and the complete commercial fertilizer all proved of value on the clover, the increases being quite pronounced in all cases. The results are too close together, however, to permit of any conclusions being drawn regarding the relative merits of the various materials. It would seem, however, that the phosphorus carriers would prove more profitable than the complete brands of fertilizers, inasmuch as these latter materials are more expensive and apparently do not bring about any larger effects.

The yields of clover on the green basis in the greenhouse experiment on the Tama silt loam from Adair county are given in table VIII. The addition of

TABLE VII. GREENHOUSE EXPERIMENT, SHELBY LOAM, ADAIR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	18.14
2	Manure	99.79
3	Manure+Lime	131.54
4	Manure+Lime+Rock phosphate	165.56
5	Manure+Lime+Acid phosphate	167.83
6	Manure+Lime+Complete commercial fertilizer	165.56

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TABLE VIII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, ADAIR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	65.77
2	Manure	92.90
3	Manure+Lime	129.27
4	Manure+Lime+Rock phosphate	156.49
5	Manure+Lime+Acid phosphate	172.36
6	Manure+Lime+Complete commercial fertilizer	161.72

manure proved distinctly profitable on the clover grown on this soil type and tho the soil is apparently very well supplied with organic matter, manure seems to be a very profitable fertilizer. The application of lime increased the yield of clover somewhat and quite generally the Tama silt loam seems to respond to this material, especially when legumes are grown. The phosphorus carriers and the complete commercial fertilizer all had some effect on the clover, the acid phosphate showing up somewhat better than the other materials. However, the differences are not very great and it is hardly possible to conclude which material should be employed on this soil. It would seem that one of the phosphorus carriers would probably prove more profitable than the complete fertilizer, inasmuch as that material is so much more expensive. Apparently this soil will respond to applications of manure, lime and phosphorus fertilizers and it must remain for field tests to determine which particular phosphorus carriers should be used.

The results of the experiment on the Shelby loam from Wayne county are given in table IX, the weight of clover in this experiment being given on the

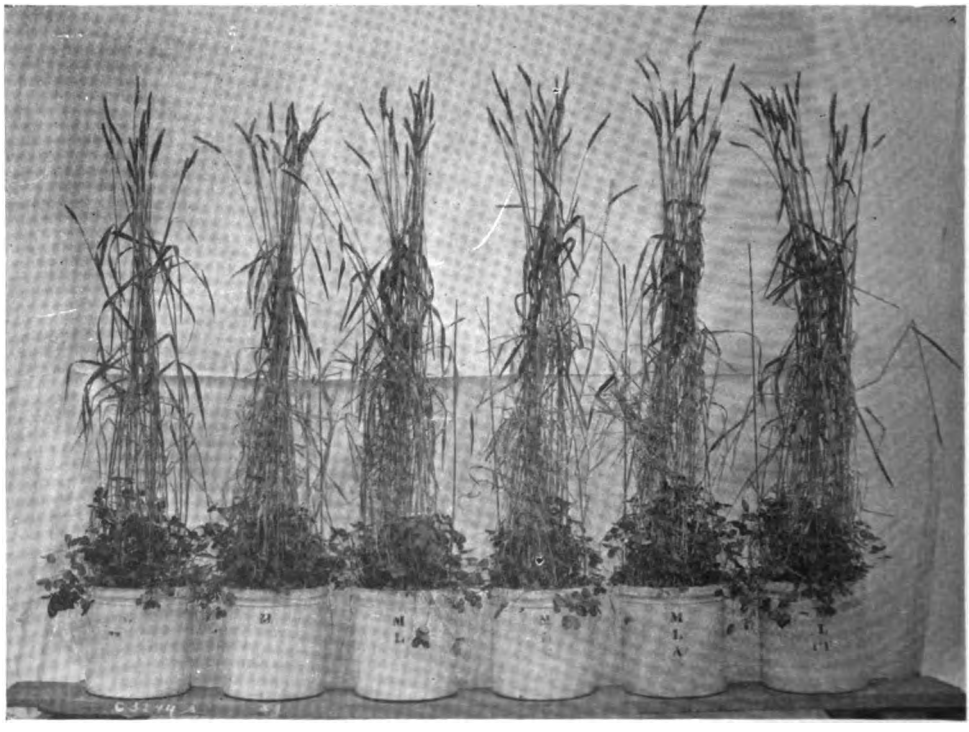

Fig. 3. Greenhouse experiment with wheat on Shelby loam in Wayne county.

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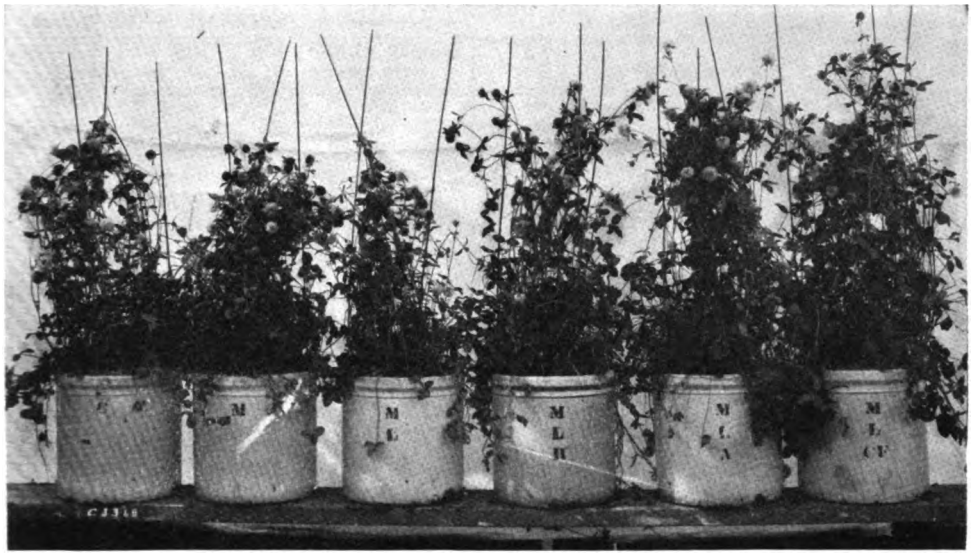

Fig. 4. Greenhouse experiment with clover on Tama silt loam, Marshall county.

dry basis. Again, as on the Shelby loam from Adair county, the application of manure brought about a distinct increase in the growth of clover. Here, however, the wheat yields were secured and a large increase in this crop from the use of manure was also noted. The lime showed no effect on the wheat, but did increase the clover, as in the preceding experiment. It would not be expected that lime would bring about any particular effect on the grain crop, the influence of this material being exerted mainly upon the legume grown in the rotation. The addition of the phosphate fertilizers and the complete commercial fertilizer proved of value on this soil, there being very little choice, however, between the three materials. The yield of clover on the commercial fertilizer pot was not secured, so the comparison of the use of these materials was not complete. It seems, however, that phosphorus fertilizers would prove of more value on this soil than the complete materials. These results confirm those secured on the same soil type in Adair county and show the large value of manure in increasing the yields of crops grown on this type. Lime is found to be of value for clover and there are indications that phosphorus fertilizers would bring about profitable crop increases. Apparently these materials will prove of greater value than the more expensive complete fertilizers. Field tests are needed to determine the relative value of rock phosphate and acid phosphate.

TABLE IX. GREENHOUSE EXPERIMENT, SHELBY LOAM, WAYNE COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Dry weight clover in grams
1	Check	18.0	36.28
2	Manure	28.0	40.82
3	Manure+Lime	28.0	43.09
4	Manure+Lime+Rock phosphate	29.0	45.36
5	Manure+Lime+Acid phosphate	28.5	45.36
6	Manure+Lime+Complete commercial fertilizer	30.2	....

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TABLE X. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MARSHALL COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Dry weight clover in grams
1	Check	19.75	45.36
2	Manure	23.00	45.36
3	Manure+Lime	23.50	49.89
4	Manure+Lime+Rock phosphate	24.00	54.43
5	Manure+Lime+Acid phosphate	27.50	72.63
6	Manure+Lime+Complete commercial fertilizer	24.00	63.50

The results of the experiment on the Tama silt loam from Marshall county are given in table X. The beneficial effect of applying manure to this soil is shown up very definitely in this experiment in the case of the wheat, but the clover does not seem to be increased in this particular case. The results on the same soil type, however, from Adair and Cedar counties, show a large effect on the clover from the use of manure. It would seem, therefore, that this material would undoubtedly prove of much value on the various crops of the rotation and that manure should be considered the most valuable fertilizing material for use on this soil. The addition of lime increased the yield of clover, but had little effect on the wheat, which is what would be expected because of the fact that wheat is not particularly sensitive to acid conditions. The addition of the phosphate fertilizers and the complete commercial fertilizers proved beneficial both on the wheat and on the clover. The acid phosphate showed up the best in the case of both crops, the complete commercial fertilizer proving somewhat superior to the rock phosphate on the clover, while

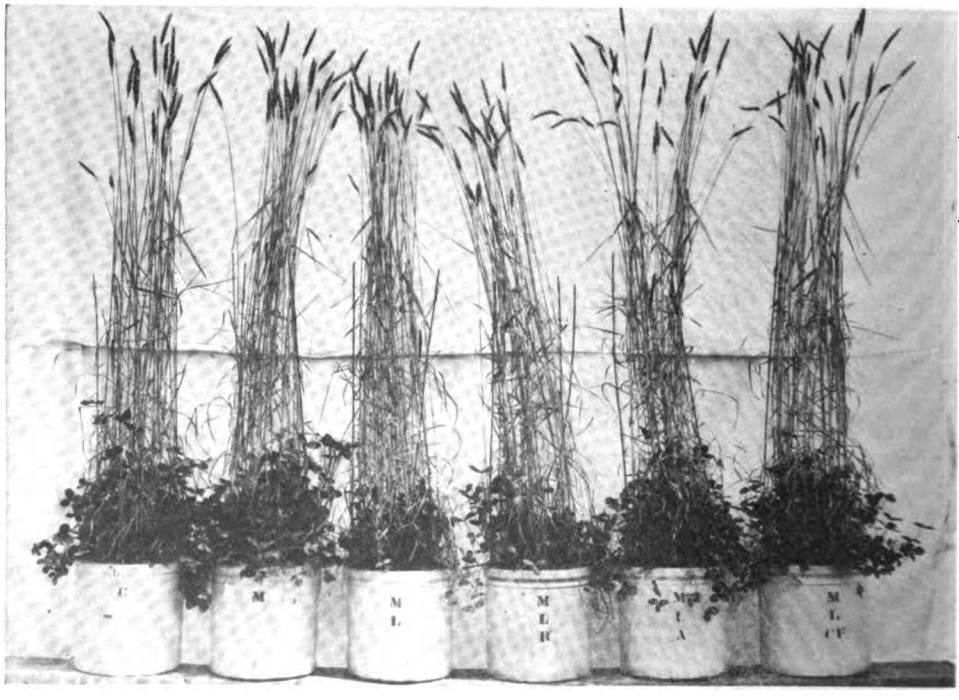

Fig. 5. Wheat and clover on Tama silt loam in Marshall county.

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TABLE XI. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, CEDAR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	4.53
2	Manure	43.09
3	Manure+Lime	58.96
4	Manure+Lime+Rock phosphate	58.96
5	Manure+Lime+Acid phosphate	106.59
6	Manure+Lime+Complete commercial fertilizer	111.13

on the wheat these two materials gave the same results. The differences, however, are not large in any case and it would seem that, while the phosphorus fertilizers would undoubtedly prove superior to the complete brands, further tests would be necessary before drawing definite conclusions regarding the relative merits of rock phosphate and acid phosphate.

The results of the experiment on the Tama silt loam from Cedar county are given in table XI. Again the weight of the clover only was secured, and on a green basis. The results, however, confirm those secured on the same soil type in Adair county and in Marshall county. The large effect of manure is particularly evident in this experiment and the addition of lime along with manure showed a large effect on the clover, as was noted on all the preceding tests. The rock phosphate showed no indications of value, but the acid phosphate and complete commercial fertilizer both brought about large increases in crop yields. The complete brand showed up somewhat better than the acid phosphate, but the difference is hardly large enough to warrant conclusions. Furthermore, the acid phosphate costs less than the complete commercial fertilizer and would probably prove the most economic material. These results would indicate a superior value for the acid phosphate over rock phosphate, as was also shown in the experiment on the same type in Marshall county. However, field tests are needed before definite conclusions are drawn along this line.

It is quite apparent from these greenhouse experiments as a whole that the Tama silt loam and the Shelby loam, the two most extensive soil types in Adair county, will respond to applications of manure, lime and phosphorus fertilizers.

FIELD EXPERIMENTS

Field experiments have been begun in Adair county, but they have not been under way long enough yet to yield results; hence, none of these experiments can be reported at present. The results obtained in Black Hawk county on the Tama silt loam, one of the important soil types in the county, may be included in this report, as the results secured are undoubtedly indicative of the needs of this soil type in general and may serve to indicate the treatments which should be practiced in the field. The data obtained on the experiments in Adair county will be given in a later publication. They are planned on much the same basis as the experiments now in progress and all these field experiments are laid out on land which is representative of the individual soil types. They are permanently located by the installation of corner stakes and the fertilizing materials which are tested are the same in all cases.

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These fields quite generally include tests under the livestock and grain systems of farming, manure being applied in the former and crop residues utilized instead of manure in the latter system. The fertilizing materials used include manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. On the grain system the same fertilizers are used, substituting the crop residues for the manure. In the field experiments thus far reported, only the livestock system experiments are given, as the crop residues have not been applied in sufficient amount to have any effect on the crop production. Manure is applied at the rate of 8 tons per acre once in a four-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil and supply 2 tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in the rotation, acid phosphate at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. The plots in these experiments are 156′ 6″x20′ in size, representing, therefore, areas of 1/10 of an acre.

THE HUDSON FIELD

The results of the experiment on the Hudson field in Black Hawk county, on the Tama silt loam, are given in table XII. The crop yields were not secured on this field in 1921, owing to an oversight on the part of the cooperator, but the yields for 1918, 1919, and 1920, are given in the table. The beneficial effect of manure, lime and phosphorus fertilizers on the Tama silt loam are shown up quite definitely in these results. Manure seems to be of particular value on this soil for corn and oats, and, if the indications from the greenhouse experiments were confirmed in the field, the clover would also show large effects from the use of this material. Apparently manure is a particularly valuable fertilizing material for the growth of general farm crops. It is interesting to note the beneficial effect of lime on the corn and oats on these plots, increases being secured in every case from the use of this material. It might be expected that the lime would show up particularly well on clover, but ordinarily the grain crops of the rotation do not seem to be benefited materially by it. Apparently, however, the improvement of the reaction of this soil is of value in bringing about larger yields of general farm crops.

Rock phosphate, acid phosphate and the complete commercial fertilizer all brought about beneficial effects on the crops grown. The difference between the effects of these various materials are, however, too small to be conclusive and in fact there are some variations in the results secured on the same crops in different seasons. It would seem evident, however, that phosphorus fer-

TABLE XII. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY, HUDSON FIELD

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Clover tons per acre 1920
1	Check	45.8	47.6	53.2
2	Manure	49.3	54.7	62.8
3	Manure+Lime	54.4	59.2	67.4
4	Manure+Lime+Rock phosphate	56.5	64.9	73.3
5	Manure+Lime+Acid phosphate	57.4	62.2	73.3
6	Manure+Lime+Complete commercial fertilizer	58.5	57.5	72.4

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tilizers would probably prove of value on this soil in many cases at the present time and tests of phosphorus carriers are urged in order to determine the exact value from the use of these materials, as well as to learn which particular phosphorus carrier should be employed. The addition of complete commercial fertilizers to this soil does not seem to be of as much value as the use of phosphorus carriers.

THE NEEDS OF ADAIR COUNTY AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The field experiments which have recently been started in Adair county will eventually yield quite definite information regarding the needs of the soils of the county. These experiments must be carried on, however, for a number of years before data is secured which will be conclusive enough to permit of the making of definite recommendations. For the present, the suggestions which are offered for the improvement of the soils of the county and the increasing of crop production are based on the results of the laboratory and greenhouse tests which have been described earlier in this report, and on a field experiment from another county, on a soil type which is the same as one of the most extensive types in this county. The results from this field experiment may be considered to indicate quite definitely the needs of this particular soil and the results which have been secured in this test very largely confirm the results of the laboratory and greenhouse tests which have been carried out on the samples from Adair county. No definite recommendations are made in this report, however, except such as have been tested to some extent by indi-

Fig. 6. Second cutting of alfalfa, showing benefits of liming. The bare part of the field, which was unlimed, produced no alfalfa at all after being clipped once.

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vidual farmers and have been proved to be of practical value by actual farm experience.

In those cases where the beneficial effects of certain methods of soil treatment have not been definitely proved by practical experience, the recommendation is made that the materials in question be tested by individual farmers. When such tests are carried out on the farm, definite information may be secured regarding the desirability of using the particular fertilizing materials under the special soil conditions. Tests are being carried out by some farmers at the present time and they are finding that the work is not complicated, and provides them with valuable information. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid farmers who are interested in carrying out tests of fertilizing materials and, until the field experiments now under way are more complete, the best suggestion which can be offered is the desirability of testing various materials on small areas. The suggestions which are given in the following pages may be put into operation under any farming conditions.

LIMING

The soils of Adair county are all acid in reaction and therefore are all in need of lime. There are only two types which are basic, even in the subsoil, and in those cases there is not a large content of lime present. These types are the Shelby loam and the Wabash clay loam. The surface soils and subsurface soils of both these types are acid. Furthermore, other samples of these types would undoubtedly prove acid in reaction in the subsoil, inasmuch as the occurrence of lime in these soils is not typical. However, even if the presence of lime in these soils were constant in the lower soil layers, there would not be a large effect on the needs of the surface soils and the use of lime to remedy the acidity occurring at the surface would be necessary. The presence of lime in the subsoil is of little significance, inasmuch as lime rarely moves upward in the soil, but tends rather to be washed out quite rapidly in the drainage water. It is apparent, therefore, that all the soils of the county should be tested for acidity and that applications of lime should be made as shown to be necessary.

Because of the constant removal of lime from well-drained, cultivated and cropped soils, one application of lime is not sufficient to keep the soils supplied indefinitely, and tests must be made at regular intervals. It is suggested that the soils of the county should be tested for lime requirement at least once in a four-year rotation, and that this material be applied as needed preceding the legume crop of the rotation. In this way the largest effects from the application will be secured. Farmers may test their own soils for acidity, but it will be much more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. In this way they will be sure to apply the amount of lime needed on the particular soil and may avoid an insufficient application or an unnecessarily large addition.

General recommendations regarding the amount of lime to be applied to soils cannot be given, owing to the fact that soils vary so widely in lime re-

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quirement. Even in the same soil type, and frequently in the same field, there will be considerable variation in the acidity of the soil. The figures given in the tables discussed earlier in this report, even tho they are the averages of tests made on several samples, are merely indicative of the needs of the individual soil types and should not be interpreted to show the exact requirements of the same soil types thruout the county. Before lime is applied to any soil, that particular soil should be tested and its exact lime need determined.

The beneficial effects of lime on soils are becoming more and more generally appreciated. Clover and alfalfa and some other legumes are particularly sensitive to a lack of lime in the soil and in some instances refuse to make a satisfactory growth unless lime is applied. Many experiments and much farm experience have shown the large crop increases obtainable by the application of lime on legumes. In many cases other farm crops are also benefited by the application of lime, even tho they are apparently not so sensitive to acid conditions. Thus, there is experimental evidence of the value of lime on soils from the standpoint of yields of corn and oats. With these crops, lime proves valuable, probably because of indirect effects on the soil conditions. Where greater legume growth is secured, the succeeding grain crops will be benefited and this may be considered an indirect effect of lime.

In general, it may be said that lime proves beneficial on acid soils because of the neutralization of acid conditions which tend to restrict crop growth, because of the improvement of the physical condition of the soil, and because of the stimulation of beneficial bacterial action. There is a constant production or increase in acidity in soils, due to the washing away of basic compounds,

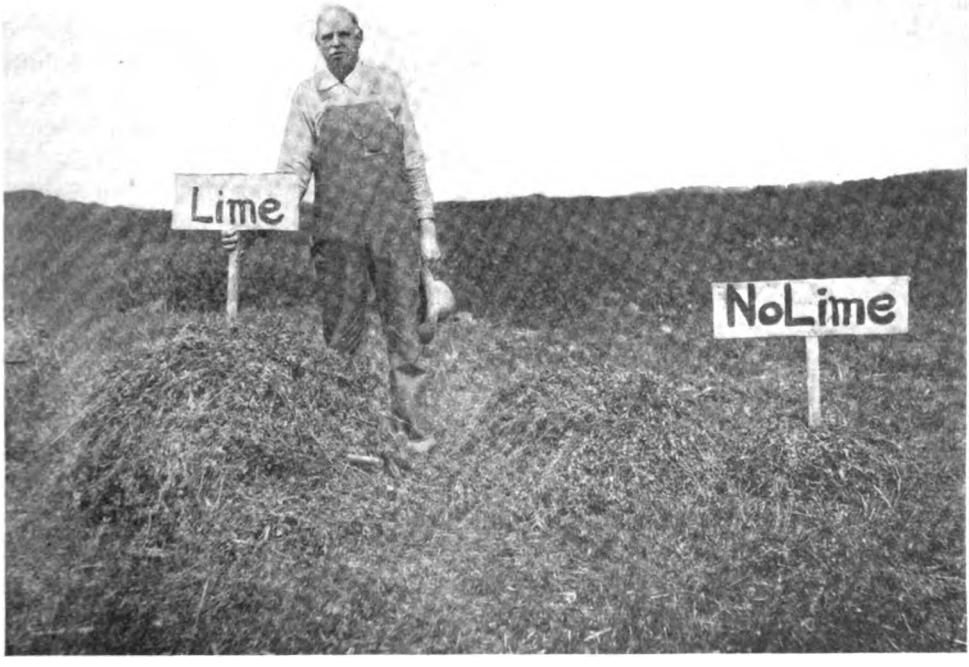

Fig. 7. An increased legume crop is a certain result when lime is used on acid soils.

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the utilization of bases by the crops grown, and the production of acids in the decomposition of organic matter, and the growth of general farm crops, particularly of legumes, will not proceed as satisfactorily where these acid conditions occur. Lime also increases crop growth by improving the physical condition of soils, opening up heavy, impervious types and making light, open soils more retentive of moisture and less subject to losses by leaching. All the desirable bacterial action is decreased by acidity and, in fact, the accumulation of acids in soils may cut down the production of available plant food to such a point that crops will suffer. The bacterial conditions in soils are improved by the addition of lime and hence the production of available plant food is increased. Probably under most soil conditions the addition of lime proves of value because of the chemical, physical and bacterial effects combined, but in some instances, and particularly in the case of legumes, the chemical effects are undoubtedly of major importance.

The expense of the application of lime is more than warranted by the value of the increased crop yields, and the farmers of Adair county may be assured that the testing of their soils and the use of lime when they are acid will yield profitable returns. Further recommendations regarding the use of lime on soils, losses by leaching, and other information connected with liming are given in Bulletin 151 of the Iowa Agricultural Experiment Station. The list of companies from which the material may be secured is given in circular 58.

MANURING

The soils of Adair county are not supplied with any considerable quantities of organic matter and in some instances there is a rather small amount of this material present, as is indicated by the light color of the soil. The application of manure is therefore a most important farm practice. The results secured from the use of this material in the way of better crop yields are definite evidence of its value. There is no other fertilizing material which has given anything like as large effects. The experiments reported in the preceding pages give evidence of the extent to which crop yields may be increased by its use, and the practical experience of many farmers in the county confirm the results of these tests.

On the soils which are rather poorly supplied with organic matter according to the analyses, manure gives especially large returns. Thus, the value of the material shows up particularly well on the Clinton silt loam, the Shelby loam and the Lindley loam, but even on those types which seem to be fairly well supplied with organic matter, crop yields are increased to a large extent by the use of farm manure. The results secured on the Tama silt loam bear evidence of the value of this material on types which are not low in organic matter, as the Tama silt loam is fairly well supplied with this material. The farmers of Adair county should keep in mind the large fertilizing value of farm manure and should see to it, therefore, that all the manure produced on their farms is carefully preserved and applied to the soils, if they are to keep up crop growth and maintain their soils permanently fertile.

The beneficial effect of manure on soils is due to its influence on the chemical, physical and bacteriological conditions. It returns to the soil a large portion

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of the plant food constituents which have been removed by the crops grown and utilized for feed. Hence, by adding plant food constituents, the life of the soil will be lengthened and the time until any one of these elements become deficient will be prolonged. Manure improves the physical condition of soils, whether heavy or light. Heavy soils are made less impervious and better aerated and the removal of excessive moisture is facilitated. Light soils are made less open and porous, more retentive of moisture and less subject to losses by leaching. The physical effect of manure on soils is frequently of great importance, and the chemical and bacteriological conditions are influenced indirectly. The evidence of these indirect effects is found in the greater production of available plant food and in the larger crop growth secured because of this fact. Applications of manure influence the bacteriological conditions in the soil directly, however, because of the addition of enormous numbers of bacteria which it contains. These organisms are very largely responsible for the production of available plant food and play an important part in increasing crop yields. The bacteria already present in the soil are stimulated to greater activities thru the addition of manure, and so there is not only a larger number of bacteria, but a very much greater action. There are probably many cases where the bacterial effects of manure are of major importance, especially on soils which are fairly well supplied with organic matter. It may be that the beneficial effect on the Tama silt loam may be due to the bacteriological influence of the material. On most soil types, however, the value of manure is undoubtedly due to a combination of the chemical, physical, and bacterial effects and in the case of the soils of Adair county, the increased crop yields which are commonly secured from the use of manure may be attributed to the improvement in all these conditions and the consequent better production of plant food.

The beneficial effect of manure is shown in the case of general farm crops and no other fertilizing material will prove of as large value if manure is not applied at the same time. When other fertilizers are employed in the county, therefore, they should be used in addition to manure, if economic results are to be secured. This statement applies, of course, only to livestock farming conditions and if manure is not available for use on the farm, some other source of organic matter must be employed.

The large increases secured from the application of manure to soils serve to emphasize the importance of preserving the manure produced on the farm in order to permit of the largest possible effects. If it is exposed in loose piles to the action of the weather and the leaching of rains, 70 to 90 percent of the valuable constituents present may be washed away. When such losses occur, crop growth is not benefited to anything like as large an extent as it should be, hence improper storage of manure may mean actual money losses because of lower crop yields.

There are various ways in which manure may be stored until it can be applied to the soil and no one method can be recommended for use under all farm conditions. It may be stored in a covered yard or pit and protected from the weather, or it may be composted, or some other method may be employed which will keep the manure moist, compact and protected from the weather. The farmers of Adair county should see to it that the manure produced on

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their farms is returned to the land with as little loss of valuable material as possible, and they may be assured that the results obtained from its application will more than warrant any expense involved in taking proper care of the material. There are some instances where manure may be applied as produced, and, in such cases, there is, of course, no storage problem, but in general the farmer must store the manure for some time before he can apply it to the land. It should be kept in mind that when not subject to extensive losses by leaching and destructive fermentation, manure may return to the land 75 to 80 percent of the plant food constituents which have been removed by the crops grown. Hence there can be no question of the importance of preserving manure with the greatest of care in order to aid in keeping up the fertility of the soils, as well as to aid in increasing crop yields.

On the average livestock farm the production of manure is unfortunately insufficient to permit of any large application to all of the soils of the farm. The usual application amounts to 8 or 10 tons per acre once in a four-year rotation. Larger applications than this may sometimes be made with profit on very light textured types and especially for truck and garden crops, but for general farm crops it is usually not desirable to apply more than 16 to 20 tons per acre, and on most farms such applications are not possible because of the small amount of manure produced. It should be remembered that if very large applications are made to one field, the remainder of the soils of the farm may suffer for a lack of organic matter and it is much more desirable to apply manure at regular intervals and in reasonable amounts to all the soils of the farm in order to keep up crop yields and keep the soils in the best condition of fertility. On the average livestock farm, there is hardly sufficient manure to maintain the supply of organic matter and nitrogen and hence some other material must be utilized to supplement the farm manure if the supply of these constituents is to be kept up. On the grain farm, some other materials must be employed as substitutes for farm manure. Under both systems of farming, therefore, there are cases where green manuring should be practiced. This involves a turning under of some green crop in the soil and, when properly practiced, may lead to considerable improvement in the soil conditions.

Leguminous crops are the most desirable for use as green manures, owing to the fact that when well inoculated they utilize the nitrogen of the atmosphere and fix it in the soil, where it serves to supply food for subsequent crops. Non-legumes may be equally valuable from the standpoint of supplying organic matter, but they do not aid in maintaining the nitrogen supply in the soil. Leguminous crops may be considered as nitrogenous fertilizers as well as sources of organic matter. When the organic matter in soils is low, the nitrogen content is usually low, also, and hence there are very few instances where legumes would not be more desirable than non-legumes for use as green manures. There are many legumes which may be grown under a wide variety of conditions and hence some one may be chosen which will fit in with almost any rotation.

There are undoubtedly cases in Adair county where green manuring may be practiced profitably, particularly where the soils are not very well supplied with organic matter and farm manure is not available for use in any considerable amounts. Green manuring is not a practice, however, which can be

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followed successfully under all conditions and it is very important that care be used in following this method of improving soil conditions. A heavy crop should not be turned under in the soil when it is dry, as there may be an injurious effect because of interference with the moisture conditions. In some cases it would undoubtedly be more desirable to plow under only a portion of the crop, rather than the entire amount, in order to secure the best results. The time of plowing under is important, as is also the depth of plowing. There are other points of importance in connection with green manuring which can only be considered in connection with individual soil conditions. The Soils Section will advise regarding green manuring under special soil conditions, upon request.

The utilization of all crop residues, such as straw and stover, is also important to aid in keeping up the organic matter content in soil. If they are burned or otherwise destroyed, as is often the case, there is an actual waste of valuable material. Not only do they supply organic matter to the soil, but they also return some of the plant food constituents which have been removed in the crops grown and thus lengthen the life of the soil. On the livestock farm, crop residues may be used for feed or bedding and returned to the soil with the manure. On the grain farm they may be stored, allowed to become partially decomposed before application, or they may be applied directly to the soil. These materials are of particular value on the grain farm, owing to the lack of manure, but they should be used just as carefully on the livestock farm in order to supplement the manure. Frequently these materials have distinctly beneficial effects on crop growth and it is very important under all systems of farming that they be properly utilized if the fertility of the soil is to be economically and permanently maintained.

THE USE OF COMMERCIAL FERTILIZERS

The analyses of the soils of Adair county have shown that the phosphorus supply is rather low in practically all cases. In fact, it seems evident that phosphorus fertilizers will need to be applied to these soils in the near future if crop production is to be kept satisfactory. Furthermore, the amount present is so low that it would seem probable that these materials could be used with profit in some cases at the present time. The total supply of phosphorus or of any other element in soils does not indicate definitely whether or not crops will be properly supplied with the particular constituent, inasmuch as crop growth is determined by the amount of available plant food rather than by the total store which is present. There is no relation between the amount of available plant food in soils and the total supply, and there is no satisfactory method of determining the amount of available phosphorus present under any particular conditions, except to apply a phosphorus fertilizer and determine whether or not it increases crop yields. But where the supply of an element is very low, it is reasonably certain that there will be an insufficient amount of that element changed into an available form.

The greenhouse experiments on the soils from Adair county indicate that phosphorus fertilizers may be of value on some of the soils of the county at the present time, and the results of the field experiment in another county on

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the same soil type confirms this indication. These results cannot be considered conclusive, inasmuch as the greenhouse tests should be confirmed by results of experiments on the same soils in Adair county, but they certainly indicate the results which may be expected on the soils of the county in general. It is very desirable that tests of phosphorus fertilizers be made under individual farm conditions in order to determine whether or not these materials may be used with profit at the present time.

If phosphorus is needed on soils, it may be applied either in the acid phosphate or the rock phosphate form. Acid phosphate contains the element in an available form, but it is considerably more expensive than rock phosphate. Rock phosphate, on the other hand, has a low rate of availability and considerably larger applications must be made. It is, however, a much cheaper material. In order to determine which of these phosphorus carriers should be used, the relative value of the crop increases secured must be determined and compared with the actual cost of the materials supplied. Rock phosphate is applied but once in a rotation, while acid phosphate is added annually. Rock phosphate does not give its largest effects the first year it is applied, and hence it is important that comparative tests of these two materials be carried on over a period of at least a four-year rotation before conclusions are drawn. The field experiments in Adair county include tests of these two materials and eventually they will show not only the need of phosphorus, but which material should be employed. The results of these field tests will be published in a later supplementary report. At present, farmers may determine the need of phosphorus and select the most desirable material by carrying out tests of rock and acid phosphate under their individual conditions. Such tests may be planned and carried out on practically any farm and with little difficulty. Directions which may be followed for testing these materials are given in circular 51 of the Iowa Agricultural Experiment Station. If profit is shown from the use of any of the materials tested, on small areas, then the same material may be applied to a large area with assurance of value. The farmers in Adair county who are interested in securing larger crops and making their soils more productive are urged to determine the value of phosphorus fertilizers under their own soil and farm conditions.

There is no large supply of nitrogen in any of the soils in Adair county and in some instances the amount of this element is undoubtedly rather low for satisfactory crop growth. It is evident that some means must be employed to keep up the supply of nitrogen in soils and in some cases efforts should be made to increase the total supply of this element. Nitrogen is removed from soils continually by cropping and by drainage and consequently there may be a very rapid decrease in the supply of this element. It is essential, therefore, that some nitrogenous fertilizer be used on the soils of the county.

The proper preservation and application of farm manure will return a large part of the nitrogen taken out of the soils by the crops grown, so that this material may be considered a very important nitrogenous fertilizer and, when it can be applied in considerable amounts, the use of other nitrogenous fertilizers may not be necessary. It is a much simpler matter, therefore, to keep up the nitrogen supply in the soil on the livestock farm, but even where farm

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manure is produced and utilized under average livestock farming conditions, there is not sufficient to provide for all the soils of the farm. On the grain farm some other sources of nitrogen must be sought. Under both systems of farming the use of leguminous crops as green manures provides the cheapest and most efficient nitrogenous fertilizer. Rotations should always contain a legume and if the legume is inoculated and the crop is properly handled, there may be an addition of nitrogen to the soil, owing to the ability of the legume to take up nitrogen from the atmosphere. Under average soil conditions only a portion of the nitrogen in the legume is taken from the air, the remainder coming from the soil, and if a part of the legume crop is removed from the land, there will generally be no addition of nitrogen thru the growth of the crop and may be an actual reduction in the total supply. In order to serve as a nitrogenous fertilizer, therefore, the legume should be utilized either in whole or in part as a green manure crop. If the seed only of the legume is removed and the remainder of the crop is turned under in the soil, there may be a distinctly beneficial effect on the nitrogen as well as on the organic matter supply. Legumes may also be employed in the rotation as catch crops and thus serve as nitrogenous fertilizers, supplying also valuable amounts of organic matter.

The proper use of all crop residues on the farm will aid materially in keeping up their nitrogen supply, because of the actual return of the nitrogen removed from the soils by crops grown. Farm manure, crop residues and leguminous green manures are much more desirable and less expensive than commercial nitrogenous fertilizers. The latter materials cannot be recommended for general use at the present time. They may be employed in small amounts as top-dressings to stimulate the early growth of some crops, but for general farm crops the use of inoculated legumes is much more satisfactory and profitable. If the commercial materials prove of value on small areas, however, they may be used without fear of injuring the soil.

Tests of many of the soils of the state which were carried out a few years ago showed a large amount of potassium in all cases, and there is no doubt but that the soils of Adair county are in general well supplied with this constituent. If it is made available sufficiently rapidly, as it usually is where the soils are kept in the best physical and chemical condition for bacterial action, there is enough to provide for satisfactory crops almost indefinitely. It would hardly seem likely, therefore, that potassium fertilizers could be used with profit in any case at the present time for the growth of general farm crops. Such materials may be employed in small amounts as top-dressings to aid the early growth of some plants, but on the average farm they would probably not prove profitable. There is no objection to the use of these materials, however, if they are tested on small areas and yield profitable returns, as they would have no injurious effects on the soil. It is very important that the soils be well drained and thoroly cultivated and that the supply of organic matter be adequate. Under such conditions, potassium will be produced sufficiently rapidly in an available form from the store already present in the soil and crops will secure all of this element that they need.

Complete commercial fertilizers contain the three essential elements, nitrogen, phosphorus, and potassium, and they usually supply these elements in an avail-

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able form. It might seem, therefore, that these materials would prove of value under many farming conditions. It is believed, however, that nitrogen can be supplied more economically in the form of leguminous green manures and potassium is hardly likely to be lacking. Hence it would seem that phosphorus fertilizers might prove more profitable. Experimental work now under way includes the testing of a complete fertilizer in comparison with rock phosphate and acid phosphate. The indications from these experiments thus far are that for general farm crops the phosphorus carriers are more desirable, owing to the fact that the complete brands are more expensive. Very large crop increases would need to be secured to make the complete brands profitable and very much larger yields than those secured by the use of acid phosphate would be required to warrant the application of the complete brand in preference to the phosphate. Eventually it is hoped that definite conclusions may be drawn regarding the comparative value of all these materials. For the present, the complete brands cannot be recommended for general use in Adair county. Farmers who are interested in any particular material may test it on a small area, compare it with a phosphorus fertilizer and, if profitable crop increases are secured, an increase which is more profitable than that produced by the phosphate, then the particular brand may be employed with the assurance of profit. There is no objection to the use of complete commercial fertilizers and they do not injure the soil. They should not be employed, however, unless they are proved to be profitable.

DRAINAGE

The soils of Adair county are generally adequately drained, but there are areas in several of the types where the installation of tile would improve soil conditions and permit of greater crop growth. The Grundy silt loam occurs on more or less level areas and the subsoil is rather impervious and, in many cases, drainage is not adequate. Small areas in the Tama silt loam where the topography is more level have been benefited by the installation of tile. There are also areas in the Shelby loam where moisture conditions are not satisfactory for the best crop growth. Occasionally in the Judson silt loam, tiling might be of value. The Wabash loam and Wabash clay loam of the bottomlands are imperfectly drained and are also subject to overflow.

Wherever moisture conditions are not satisfactory, the installation of tile would prove of value from the standpoint of increased crop production. No other soil treatment will prove of value if the soil is poorly drained. The first treatment needed to insure satisfactory crop growth is to take care of the removal of excess moisture. The installation of tile may be rather expensive, but the results secured in the way of increased crop yields will more than warrant the expense. In general it may be said that while the soils of Adair county are fairly well drained, there are some instances where tiling would prove of value and the farmers of the county should see to it that they are not limiting their crop yields because of unsatisfactory moisture conditions which might be remedied by laying a line of tile.

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THE ROTATION OF CROPS

The continuous growing of any one crop very rapidly reduces the fertility of the soil and so is a very undesirable practice. Furthermore, continuous cropping is not a profitable practice, even if the particular crop is of considerable value. Less income from the land will be secured over a period of years than where a rotation has been employed. This is due to the fact that crop yields under a system of continuous cropping are very rapidly decreased, while under a rotation good yields may be maintained, or even increased, and even tho less valuable crops are included, the returns from the soil will be greater. No specific rotation experiments were carried out in Adair county, but several rotations may be suggested which have proved satisfactory thruout the state, and from among these, some one may be chosen as suitable for use in this county. These rotations may be modified as seems desirable and, in fact, almost any rotation may be employed, provided it contains a legume and a money crop.

I. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.)
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy.)
Fourth Year—Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year—Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain.)
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn, stover, and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur; hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will, of course, wash over it, and much of the soil may be carried away in this manner, to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to

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erosion, while heavy soils such as loams, silt loams and clays, may suffer much from heavy or long-continued rain. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or, if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and the absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues, if soil subject to erosion is to be properly protected. By the use of such materials, the absorbing power of the soil is increased, and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. With all these treatments, the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but is less harmful and is

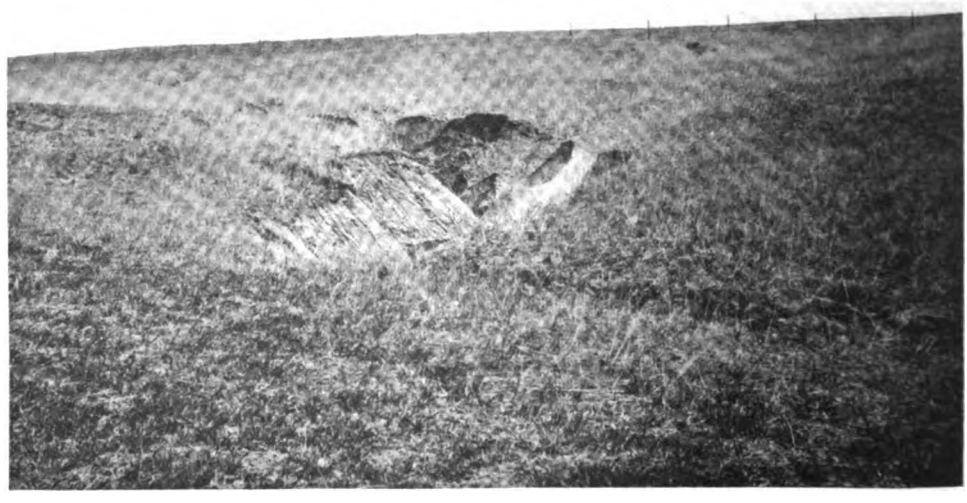

Fig. 8. Erosion is a serious problem over much of the Shelby loam area.

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usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked, an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

Erosion occurs to a considerable extent in several of the soils of Adair county, the Shelby loam, Lindley loam and Clinton silt loam being particularly subject to this injurious action. The Tama silt loam is also affected to a considerable extent and, in fact, the shallow phase of this type is a result of extensive erosive action. It is very important that some means be taken to protect all these soils from the injurious effect of erosion and from among the methods suggested here, one may be chosen which will serve under almost any condition. There are probably some cases where the soil should preferably be left in pasture if extensive washing is not to occur. The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and, in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways, but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

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Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls, and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch, but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is most desirable before any success can be had in filling small or large gullies.

"Staking In." The simplest method of controlling small or moderate-sized gullies, and the one that gives the most general satisfaction, is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as rapidly by the action of a large volume of water. A series of these brush-piles may be installed up the course of the gully and, with the regular repair of washouts or undercuttings, may prove very effective.

Fig. 9. Stakes across this gully, supplemented by brush and straw, are checking erosion in Shelby loam.

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The modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of 4 to 10 feet, depending upon the width of the ditch. Brush ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend, of course, upon the size of the gully. These posts should be set well into the ground and spaced about 4 feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

The Straw Dam. A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is long or branching, it should be placed near the middle or below the junction of the branches, or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material, and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water, the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff, to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully, and higher in the center than at the sides, to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" had been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies, and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints, and it is recommended that the inlet to the tile be protected from clogging by the installation of posts

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supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an upstream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound, they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish, even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, in the same way as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven-wire, especially in connection with brush or rubbish, has sometimes proved satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and, for quick results, sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. This dam is, however, rather expensive. Then too, it may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to the high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water-absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface, and consisting of depressions or holes filled with coarse gravel and connected

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with the tile, help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may generally be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and, especially where such low-lying areas are crossed by small streams, the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished in any community and, while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows, which extend up the drainage channels. While the method has some good features, it is not generally desirable. The rows of trees often extend much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity, because of their shade and because of the water which they remove from the soil. In general, it may be said that in pastures, bottomlands and gulches, the presence of trees may be effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil, and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose, or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues, such as straw and corn stalks, may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also desirable

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for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and has proved quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall-plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion, as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall, as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil may therefore be reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value, both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN ADAIR COUNTY*

There are eight individual soil types in Adair county and these, together with the shallow phase of the Tama silt loam, make nine soil areas in the county. These are divided into four large groups, according to their origin and location, known as drift soils, loess soils, terrace soils, and swamp and bottomland soils.

DRIFT SOILS

There are two drift soils in the county, classified in the Shelby and Lindley series. Together they cover 37.9 percent of the total area.

SHELBY LOAM (79)

The Shelby loam is the largest drift soil in the county and the second largest soil type, covering 36.4 percent of the total area. It occurs in all parts of the county in considerable areas, the only portion where it is not found extensively being the northeast corner. It occurs on the slopes between the stream bottoms and the areas of upland Tama. Thus it is developed in strips bordering the slopes of valleys and ravines and it also is found in some broader and more continuous tracts near the larger streams.

The surface soil of the Shelby loam is a brown to dark brown loam or gritty silt loam to a depth of 8 to 12 inches. It grades below this point into a loamy

*The descriptions of the individual soil types given in this section of the report very closely follow those given in the Bureau of Soils Report.

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sandy clay, brown or yellow in color, mottled with brown, yellow and gray. Below 20 to 24 inches it is somewhat lighter in color and the mottling is more pronounced. In the southeastern part of the county, there is a higher content of sand in the soil than in other parts of the area. The character of the soil material varies considerably, especially where the type joins the Tama silt loam and the shallow phase Tama. Frequently the boundary lines between these types is very difficult to draw. The subsoil of the type frequently contains calcareous material and it also contains black iron concretions.

In topography the Shelby loam varies from sloping and rolling to somewhat hilly. Along the south side of the eastward or westward flowing streams, the areas are steeper and more broken than are areas on the slopes descending from the north. Drainage is generally good, altho in some depressions along small streams there may be narrow swales and seepy places. Some erosion is constantly occurring in the type and gullies are of rather frequent occurrence.

About one-half of the Shelby loam is under cultivation, the remainder being utilized for pasture and hay land. Originally this type was forested, and on the steeper and more broken areas there is still a scrubby growth of white, black and bur oak and some hickory, elm, and hazel brush. In the cultivated areas, corn is the most important crop grown, followed by oats and wheat. Barley, rye, millet, Sudan grass, sorghum and alfalfa are minor crops on this type. Corn yields from 25 to 60 bushels per acre, oats from 40 to 50 bushels, wheat 15 to 25 bushels, and barley 20 to 30 bushels per acre. Timothy and clover produce 1 to 2 tons of hay per acre, the wild grasses giving smaller yields. The type ordinarily supports good pastures, which are largely bluegrass.

Yields of general farm crops may be increased on the Shelby loam thru the proper handling of the soil. It is chiefly in need of organic matter and should receive liberal applications of farm manure on the cultivated portion, if the

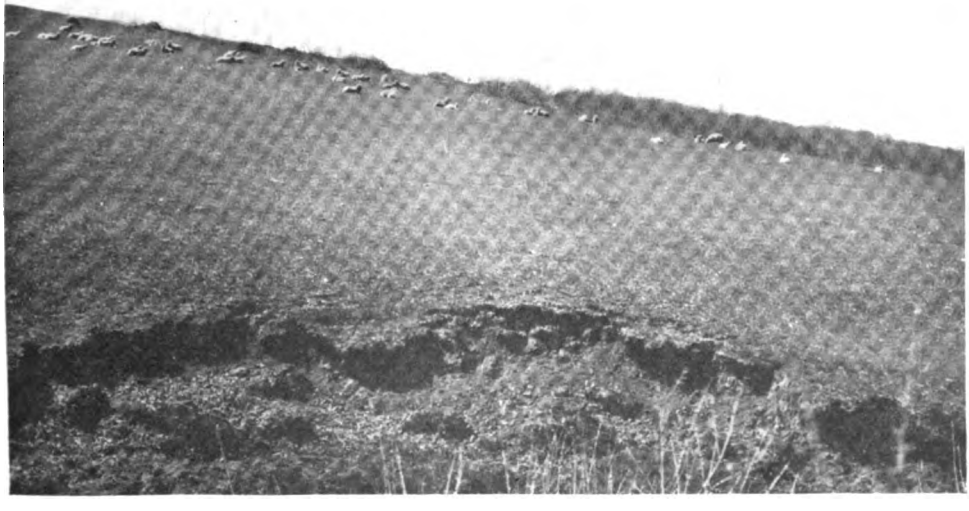

Fig. 10. Shelby loam slopes make fine pasture.

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Fig. 11. Shelby loam topography is sloping and rolling, often hilly.

best crop yields are to be secured. The type is usually acid in reaction and the application of lime would prove of value where legumes are to be grown. The small amount of lime occasionally occurring in the subsoil will not appreciably affect the lime requirement of the surface soil. The type is low in phosphorus and applications of phosphorus fertilizers will undoubtedly be needed in the future, if they do not prove of value at the present time. There are indications from field tests and farm experience, however, that phosphorus may prove a profitable fertilizer for use on this soil now. The soil certainly will respond to liberal applications of manure and, if manure is not available in sufficient amounts, leguminous crops should be employed as green manures in order to increase the supply of organic matter and nitrogen. The soil is subject to erosion and the washing away of valuable soil, whether thru gully formation or thru sheet washing, should be prevented by adopting some one of the methods of control suggested earlier in this report. There are undoubtedly some areas of the Shelby which are too rough for the growing of cultivated crops and, in these locations, the type should be left in pasture.

LINDLEY LOAM (65)

The Lindley loam is a minor type in the county, covering only 1.5 percent of the total area. It is, however, the second most extensive drift soil. It occurs mainly in two areas in the county, one along the Middle river in the vicinity of Arbor Hill, and the other along the Middle Nodaway river and the West Fork Nodaway river, west of Avondale Church. Other small areas of the type occur chiefly on the eastern boundary of the county.

The surface soil of the Lindley loam consists of 6 to 7 inches of grayish to yellowish-brown loam or silty loam. Below this point it becomes a friable yellow brown silt loam which, at 24 inches, shows considerable fine and very fine sand and mottlings of gray and rusty brown. Below 30 inches the soil in

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places is mottled with reddish-brown and is compact and sticky. Gravel occurs thruout the surface soil and subsoil.

In topography the type is rolling to broken and very little of it is suitable for cultivation. Most of the type is used for pasture and much of it is forested, chiefly with oak, hickory, elm and hazel brush. There are a few areas where general farm crops may be grown with success and here the yields are very much the same as on the Shelby loam. In the more rolling areas the soil is cut by small streams and gullies and the surface material is constantly being washed away thru erosion.

The first treatment needed in most cases, if this soil is to be used successfully for cultivated crops, is to prevent the destructive action of rain-water in washing away the surface soil. The addition of organic matter in the form of barnyard manure or leguminous green manures is very important on the cultivated areas in order to cut down erosion to a minimum and also to improve the soil conditions. The soil is acid and in need of lime and if legumes are to be successfully grown this material must be employed. The phosphorus supply is low and phosphorus fertilizers may be of value at the present time and certainly will be needed in the future.

LOESS SOILS

There are three loess types in the county and these, together with the shallow phase Tama, make four loess soil areas. Together they cover over one-half the total area of the county, 51.6 percent. They are classified in the Tama, Clinton and Grundy series.

TAMA SILT LOAM (120)

The Tama silt loam is the largest loess type, and also the largest individual soil type in the county. Together with the shallow phase, it covers 50.4 percent

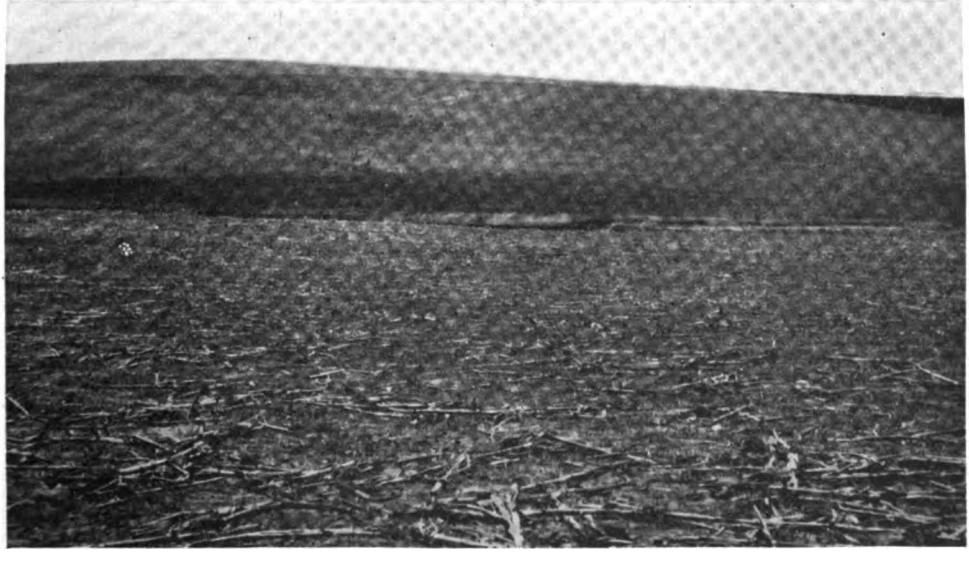

Fig. 12. About one-half the Shelby loam in Adair county is under cultivation.

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Fig. 13. The Tama silt loam is gently undulating to slightly rolling, and is practically all under cultivation.

of the total area. It occurs in more or less extensive areas in all parts of the county, occupying the more gently undulating to slightly rolling uplands, the area between the various streams and intermittent drainageways. It is usually separated by the more steeply rolling Shelby from the bottomlands along the streams.

The surface soil of the type is a dark brown to nearly black heavy silt loam to silty clay loam, 12 to 20 inches in depth. In the lower part of this surface layer the soil grades into a light brown to light yellowish-brown more compact silt loam or silty clay loam. It becomes somewhat lighter colored at 24 to 30 inches and frequently contains gray, yellow and brown mottlings. In topography the type is nearly level or undulating to gently rolling. The soil is well drained, except in a few shallow depressions at the heads of draws and in a few of the flatter areas.

Practically all of the type is under cultivation and corn, oats, wheat, and barley are the principal crops grown. Corn yields from 30 to 70 bushels per acre, the average yields amounting to 40 to 45 bushels. Oats yield from 40 to 60 bushels per acre, winter wheat from 15 to 30 bushels, spring wheat from 8 to 15 bushels and barley from 20 to 25 bushels per acre. Timothy yields 1 to 1½ tons of hay per acre and other forage crops include sorghum, Sudan grass and alfalfa.

Altho this soil is quite satisfactorily productive, crop yields may be increased thru proper systems of management. The type is acid and in need of lime, if legumes are to be grown successfully. It is not strikingly deficient in organic matter, but applications of manure prove of distinct value and this material should be applied in as large quantities as available. The soil is not very well supplied with phosphorus and phosphorus fertilizers will certainly be needed in the future, if they do not prove of value at the present time. There are indications from some of the experimental work, however, that these materials will yield profitable returns now. Occasionally the type is in need of tiling, but ordinarily the drainage conditions are very satisfactory.

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TAMA SILT LOAM (Shallow Phase) (143)

This phase of the Tama silt loam is minor in area, covering about 10 percent of the total area of the county. It occurs in numerous areas, especially around the heads of draws and on slopes along the stream courses, especially the southern slopes. Many of the areas separate the typical Tama of the more level uplands from the rolling to rough Shelby on the slopes to the bottoms. Occasionally it occurs on the areas adjoining the drainage channels and separates the upland soils from the bottomland types.

The surface soil of this phase is a grayish-brown to dark brown silt loam or silty clay loam, 6 to 12 inches in depth. The subsoil is a light brown or dull yellow moderately friable silty clay loam, in many places mottled with gray and brown. In general the lower part of the three foot section is characterized by a lighter color and more pronounced mottlings.

In the extreme southwestern corner of the county there is a variation from the typical phase where the soil is underlaid by a stiff plastic subsoil, light brown in color, mottled with gray, yellow and brown. On the lower parts of slopes the phase may usually be as deep as and have other characteristics similar to the typical silt loam, while up on the slopes, the surface material may be washed away to such an extent that the underlying glacial till is exposed, giving small patches of the Shelby loam. There are certain areas where the mapping of this phase is rather difficult, owing to overlapping with the Shelby loam. The topography of the type is rolling and drainage is usually good. There are a few cases where small depressions and swales lead to unsatisfactory drainage and, in these instances, tiling should be practiced.

This phase of the Tama silt loam is undoubtedly chiefly in need of protection from erosion if crop yields are to be made satisfactory. The phase has been formed mainly from the removal of the surface soil, and the continued washing action will eventually remove all the loessial material and the underlying drift

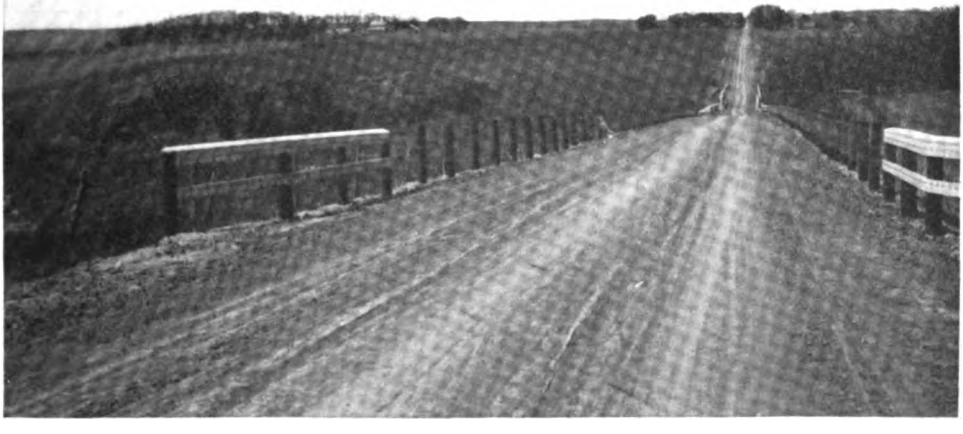

Fig. 14. A well-graded and dragged highway in the Tama silt loam, Adair county.

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formations will appear at the surface. The introduction of organic matter into the soil is of value and, if farm manure is not available for use, it would be very desirable to turn under a legume crop as a green manure. The incorporation of organic matter with the soil is of value because it reduces the injurious washing by rains and also because of the aid which it gives in producing better soil conditions from the more or less infertile subsoil material which is constantly being brought up thru plowing and mixed with the shallow surface material. The type is acid and in need of lime and will undoubtedly respond to applications of phosphorus fertilizers.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type in the county, covering 0.7 percent of the total area. It occurs entirely in the eastern part of the county, mostly in the eastern parts of Harrison and Grand River townships, where it joins the areas of the same type in Madison county. It occurs on the ridges and many of the slopes, altho it is occasionally associated with the Lindley and Shelby types.

The surface soil of the Clinton silt loam is a dark grayish-brown friable silt loam about 8 inches in depth. Below this point it becomes a compact, tho friable, light brown silty clay loam, which becomes somewhat lighter in color and less friable in structure at 24 to 28 inches. Mottlings of brown and gray occur and there are also black concretions present.

In topography the type is undulating to rolling, with a few sharply rolling areas. Drainage is well established. Most of the type is in farm land, but some of the more rolling areas are still in forest. The tree growth present includes oak, hickory, elm and box elder.

In the cultivated portions the crops grown are much the same as on the Tama silt loam. The yields, however, are somewhat smaller. The soil is particularly in need of applications of farm manure or the use of leguminous green manures to make it more productive. When cultivated, it should be protected from erosion thru special methods of treatment. It is acid and in need of lime. It is low in phosphorus and for general farm crops, phosphorus fertilizers could probably be used with value.

GRUNDY SILT LOAM (64)

This is a minor type in the county, covering 0.5 percent of the total area. It occurs mainly in the northeastern corner of the county, southeast and east of Stuart. There are small areas, also, in the south central part of the county, near Orient. It is found in irregular-shaped areas on flat ridge tops surrounded by the Tama silt loam.

The surface soil of this type is a dark brown or nearly black friable silt loam, resting on a more compact silty loam, which at 20 to 24 inches changes into a drab rather plastic clay loam, more or less mottled with gray and dull brown. At 28 to 30 inches the subsoil is a compact plastic silty clay, mottled with bright yellow, drab and rusty brown.

In topography the soil is nearly level and owing to this fact and to the impervious subsoil condition, drainage is poor. The installation of tile is the first treatment needed to make this soil satisfactorily productive. Applications of

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farm manure would be of value. The soil is acid and in need of lime. It is not very well supplied with phosphorus and a phosphorus fertilizer might be used with value at the present time. It certainly will be needed in the future.

TERRACE SOIL

There is one terrace type in the county, classified in the Judson series. It covers only a small portion of the total area, 0.5 percent.

JUDSON SILT LOAM (131)

This type occurs mainly along Middle river in numerous small areas, the largest of which are found in the vicinity of Arbor Hill. A few small areas are found in the western part of the county along the Middle Nodaway river and West Fork Nodaway.

The surface soil of the Judson silt loam consists of a dark brown to dark grayish-brown silt loam, 10 to 14 inches in depth. Below this point the soil becomes a somewhat heavier, but friable, silt loam or silty clay loam, light brown in color, and at 22 to 24 inches this becomes more compact. In many of the depressions and lower lying areas, mottlings of gray and brown are found in the lower part of the 3-foot section. In a few of the smaller areas the surface soil is somewhat lighter than typical, ranging from a light brown to a grayish-brown. In topography, the soil is nearly level or very slightly undulating. Except in a few depressed areas, drainage is good. In only a few instances would tiling be necessary.

Practically all of the type is utilized for cultivated crops, only a few small areas being handled, along with the Wabash soils of the bottom, in permanent pasture. The yields of general farm crops are quite satisfactory, but may be increased thru proper soil treatment. Manure may be applied with value. The soil is acid and should be limed. Phosphorus fertilizers might be used to advantage in some cases.

SWAMP AND BOTTOMLAND SOILS

There are two swamp and bottomland soils in the county, both belonging in the Wabash series. Together they cover 10.0 percent of the total area.

WABASH LOAM (49)

The Wabash loam is the larger of the two bottomland soils, covering 8.4 percent of the total area of the county. It occurs in all parts of the county, bordering nearly all of the smaller streams and most of the larger ones. The most extensive areas of the type are found along the Middle Nodaway river and the West Fork Nodaway.

The surface soil of the type is a dark brown friable loam, 8 to 12 inches in depth. Below this point the subsoil is a grayish-black, dark slate colored, or nearly black heavy loam to silty clay loam. In many places faint mottlings of brown are found at 24 to 30 inches. In some of the narrower areas there are variations, both in color and texture, from the typical Wabash loam, and in these areas there may be a grayish-brown gritty loam or heavy sandy loam

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Fig. 15. Pasture on Wabash loam in the bottoms, with Shelby loam in the background.

which, at a depth of 4 to 12 inches, rests on a dark brown to black loam or silt loam. The soil near the stream channels is generally lighter in texture than that further back. Pockets or layers of sandy material may be found in any part of the 3-foot section. The upper subsoil is frequently a dense plastic clay.

In topography the Wabash loam is level and slightly sloping. Here and there it may slope gradually toward the uplands and have some covering of colluvial material, especially in the narrower valleys. The drainage of the type, as a rule, is good, but there are areas where the removal of excessive moisture would be very desirable. Most of the type is subject to overflow regularly and if used for cultivated crops, would need to be protected from flood waters.

The larger part of the type is used for pasture land. Some areas, especially along the stream channels, are timbered with elm, willow, cottonwood, walnut and some oak. Where well drained and protected from overflow, corn and other general farm crops may be grown successfully. Corn yields 20 to 70 bushels per acre and average yields are around 40 to 50 bushels. Oats yield from 30 to 40 bushels and wheat 15 to 25 bushels per acre. Red clover is produced on well drained areas, white clover and bluegrass do well on the more poorly drained areas. Some wild grasses are cut for hay, yielding ½ to 1 or more tons per acre.

This type is mainly in need of protection from overflow and adequate drainage, if cultivated crops are to be grown successfully. Small applications of farm manure would be of particular value when the soil is newly drained. The type is acid and in need of lime. Phosphorus fertilizers will be needed in the future, if they do not prove of value at the present time.

WABASH CLAY LOAM (63)

This is a minor type in the county, covering 1.6 percent of the total area. It occurs mainly in the southwestern part of the county, along the West Fork

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Nodaway river. Small areas are found in the northeastern part of the county around Plunger Run and North river.

The surface soil of this type is a dark brown to black clay or silty clay loam, 8 to 10 inches in depth. The subsoil is a nearly black compact clay to silty clay. There is usually very little change in the subsoil conditions to a depth of 3 feet, but sometimes at 24 to 30 inches, the soil may become somewhat lighter and mottlings of brown or yellowish-brown may appear. When wet, the surface soil is sticky and, when dry, it becomes hard and cracks. Small areas where the soil is particularly stiff are known locally as "gumbo" and in such areas the handling of the soil, if cultivated, is of special importance. In topography, the type is nearly level and in many of the areas, drainage is fairly well established. In the lower lying portions, however, drainage is inadequate. The type is subject to overflow.

Most of the soil is utilized as pasture land and affords good grazing. On the cultivated portion, corn is the chief crop grown and yields are very much the same as on the Wabash loam. The type is in need of drainage and protection from overflow, if it is to be brought under cultivation. It will respond to small applications of farm manure. It is acid and should be limed and phosphorus fertilizers will probably prove of value.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

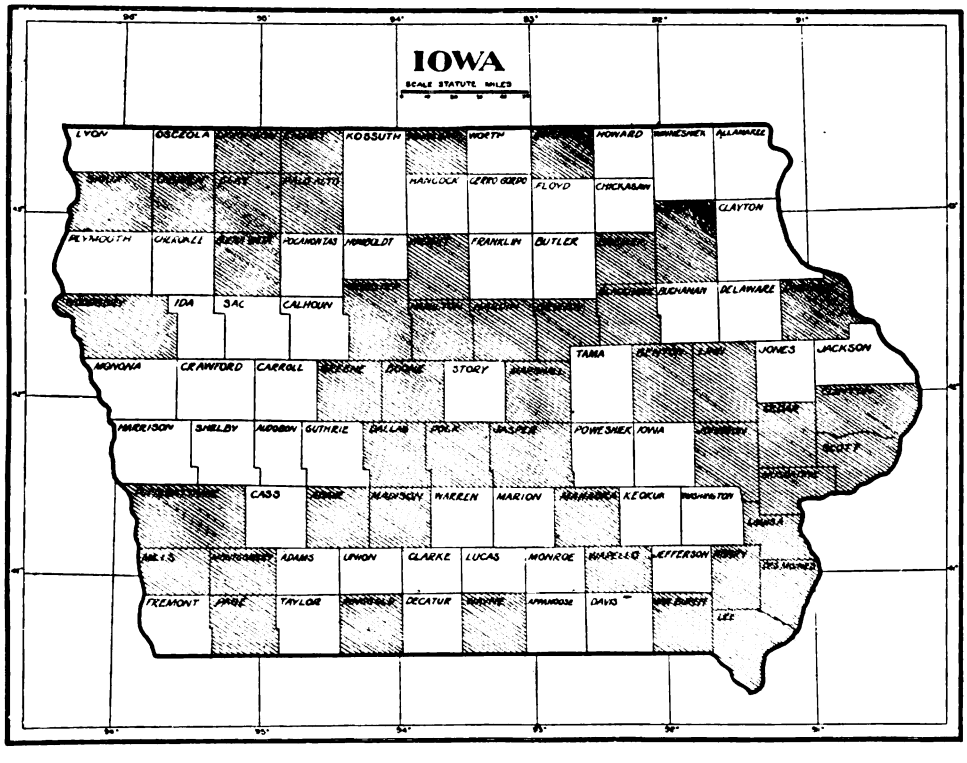

Fig. 16. Map of Iowa showing the counties surveyed.

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The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accummulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavail-*

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

able. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phos-

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phorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still

*Bulletin 150, Iowa Agricultural Experiment Station.

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present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

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But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 percent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less

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distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 17.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

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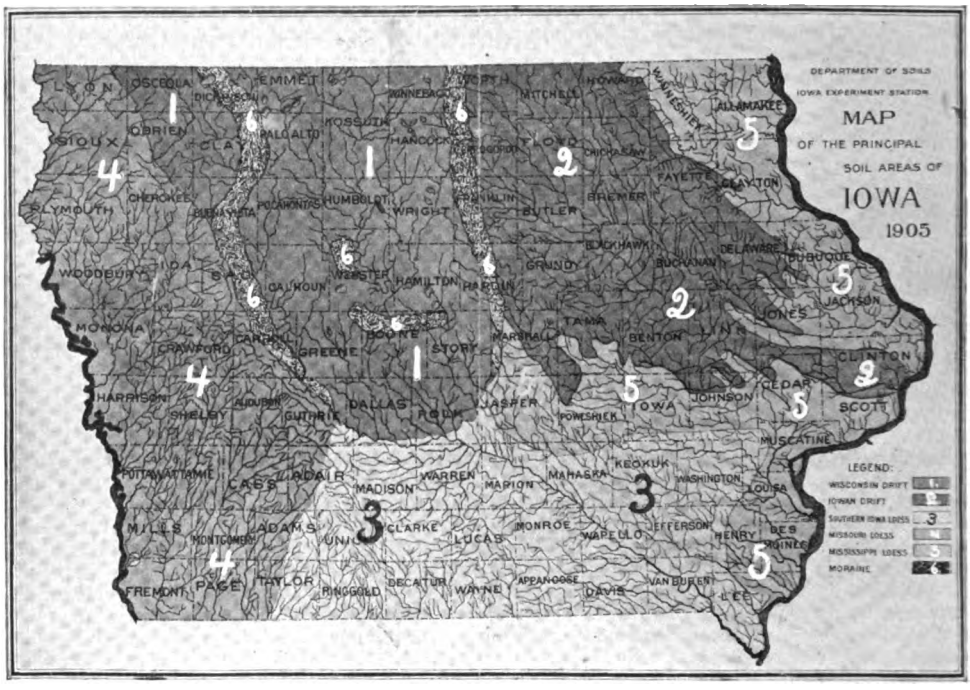

Fig. 17. Map showing the principal soil areas in Iowa

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.

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2. The topography or lay of the land.

3. The structure or depth and character of the surface, subsurface and subsoil.

4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.

5. The texture or porosity, granulation, friability, plasticity, etc.

6. The color of the strata.

7. The natural drainage.

8. The agricultural value based upon its natural productiveness.

9. Native vegetation.

10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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June, 1922 Soil Survey Report No. 28

SOIL SURVEY OF IOWA

Report No. 28—CEDAR COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of A. M. O'Neal, Jr., L. W. Forman and D. S. Gray

Typical Cedar county farmstead.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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CEDAR COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of A. M. O'Neal, Jr., L. W. Forman and D. S. Gray

Cedar county is located in eastern Iowa in the second tier of counties west of the Mississippi river and nearly midway in the state north and south. It lies partly in the Mississippi loess and partly in the Iowan drift soil areas and hence the soils in the county are partly loessial and partly glacial. By far the larger portion of the county, however, is covered by the loess deposits.

The total area of Cedar county is 570 square miles or 364,800 acres. Of this area 350,085 acres, or 95.9 percent, is in farm land. The total number of farms is 2,468 and the average size of the farms is 144 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the utilization of the farm land in the county:

Acreage in general farm crops	211,095
Acreage in pasture	119,850
Acreage in farm buildings, feedlots and public highways	15,366
Acreage in waste land	2,097
Acreage in crops not otherwise listed	110

The type of agriculture practiced in Cedar county consists mainly either of livestock farming or a system of general farming which includes the production of general farm crops and some livestock feeding. The livestock industry has developed to a large extent and the raising and fattening of beef cattle and hogs are practiced extensively. Dairying is an important industry in the county and there is some market gardening and fruit growing. The latter industries, however, are practiced chiefly to supply the home demand. The income from the farms of the county in general is derived mainly from the sale of beef cattle and hogs and from the sale of dairy products.

Very little of the corn, oats and other farm crops produced in the county is sold to outside markets with the exception of wheat, the greater portion of this crop being sold to elevators and shipped to outside markets. The corn, oats and hay are practically all utilized for the feeding of work stock and dairy cattle or for fattening beef cattle and hogs, leaving very little surplus of these crops in average seasons for outside sale. The minor general farm crops grown in the county and the market garden and fruit crops are all utilized to supply the home demand.

The area in waste land in the county is rather large and some method of treatment should be adopted which would permit of the reclamation of these areas. General recommendations for the best treatment of such land cannot be given inasmuch as the causes of infertility are so variable. In a later section of this report special treatments which are particularly desirable for individual soil conditions will be indicated. In special cases for more or less abnormal conditions, advice regarding the treatment needed may be secured upon request from the Soils Section of the Iowa Agricultural Experiment Station.

*See Soil Survey of Cedar county, Iowa, by A. M. O'Neal, Jr., of the U. S. Department of Agriculture and D. S. Gray of the Iowa Agricultural Experiment Station.

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CEDAR COUNTY'S CROPS

The general farm crops grown in Cedar county in the order of their importance are: Corn, hay, oats, barley, wheat, potatoes, rye, alfalfa. The average yields and value of these crops grown in the county are given in table I.

Corn is the most important crop, both in acreage and value. It is grown on almost a third of the farm land of the county and average yields of 51 bushels per acre are secured. Practically all of the corn produced is used on the farms for fattening beef cattle and hogs and for feeding work stock and dairy cattle. A small part of the crop is cut annually for ensilage. In some years a small part of the corn produced is sold to the elevators and shipped to outside markets, but in general very little of the crop is disposed of in this way.

Hay is the second crop in acreage and value, yields of tame hay amounting to 1.4 tons per acre. There is only a very small acreage of wild hay in the county and the hay crop in general consists mainly of timothy and clover mixed. Some clover and timothy are grown alone. Practically all of the hay produced in the county is fed on the farms.

Oats is the third crop of importance and it is grown on practically all farms as a part of the rotation system. The area in this crop is somewhat smaller than that in tame hay and the value of the crop is less at the present time. Under better market conditions with better prices the value of this crop would be greater than that of hay. Average yields of oats amount to 46 bushels per acre. The total yield of this crop in 1920 was over two million bushels. The oats produced in the county are practically entirely used for feed for beef cattle, hogs, dairy cattle and the work stock on farms.

Barley is a rather important crop in the county, occupying 2.6 percent of the total farm land. Average yields amount to 27 bushels per acre and the value of the crop is considerable. Barley is frequently used in place of oats in the rotation. Nearly all of the grain produced is fed on the farms and only a small percentage is shipped out of the county.

Wheat is grown to some extent in the county, about the same acreage being devoted to the spring varieties as to the winter varieties. Average yields of spring wheat amount to 15 bushels, while the winter wheat yields 23 bushels per acre on the average. Practically all of the wheat produced is sold to the elevators and most of it finds its way to outside markets.

TABLE I. AVERAGE YIELD AND VALUE OF CROPS GROWN IN CEDAR COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	99,400	27.9	51.0	5,069,000	$0.47	$2,382,430
Oats	44,200	12.4	46.0	2,033,200	0.36	731,952
Spring wheat	2,200	0.6	15.0	33,000	1.35	44,550
Winter wheat	2,700	0.7	23.0	62,100	1.41	87,561
Barley	9,320	2.6	27.0	251,640	0.63	158,533
Rye	740	0.2	18.0	13,320	1.17	15,583
Potatoes	825	0.2	100.0	82,500	1.22	100,650
Tame hay	51,450	14.4	1.4	72,030	16.24	1,169,767
Wild hay	170	0.04	1.2	204	12.69	2,588
Alfalfa	90	0.02	3.0	270	19.23	5,102
Pasture	119,850	33.7	....	.....	....	.....

*Iowa Yearbook of Agriculture, 1920.

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Potatoes are grown on practically every farm and average yields amount to 100 bushels per acre. The total value of the potato crop in the county is rather considerable. The entire crop is used locally.

Rye is produced to some extent but is relatively an unimportant crop. Some alfalfa is grown and average yields amount to 3 tons per acre. When soil conditions are made suitable, very satisfactory yields of alfalfa may be secured. With more information regarding the precautions to be taken in order to secure a stand, the crop will undoubtedly become more popular and will be grown more extensively in the county. Buckwheat is grown to some extent and popcorn and sorghum are produced on small areas.

The growing of sweet corn has increased considerably, several thousand acres being devoted to this crop in 1918. The product is disposed of at the canning factory at Tipton. Some truck crops are grown, particularly watermelons and canteloupes, which prove very satisfactory in the southern part of the county on the sandy terraces of the Cedar river. Strawberries and raspberries are produced on a few farms but these small fruits are not grown very extensively. Apple orchards are occasionally maintained on the farms but they receive little attention and do not go far even toward supplying the home demand.

CEDAR COUNTY'S LIVESTOCK BUSINESS

The livestock industries of the county include the raising and feeding of beef cattle and hogs, dairying, the raising of horses, the raising and feeding of sheep, and poultry raising. The following figures taken from the Iowa Yearbook of Agriculture for 1920 show the extent of the livestock industry in the county:

Horses, all ages	13,761
Mules, all ages	925
Swine (on farms July 1, 1920)	162,817
Swine (on farms January 1, 1921)	114,850
Cattle (cows and heifers kept for milk January 1, 1921)	10,652
Cattle (other cattle not kept for milk January 1, 1921)	43,103
Cattle (total all ages)	53,755
Sheep (all ages on farms January 1, 1921)	14,474
Sheep (shipped in for feeding 1920)	7,444
Sheep (total pounds of wool clipped)	61,616
Poultry (total all varieties January 1, 1921)	285,346
Poultry (number of dozen eggs received 1920)	1,014,624

On practically every farm in the county some beef cattle are fed and herds range from 7 to 30 in number. The smaller herds are either raised or bought locally while the larger operators bring in carload lots from St. Paul, Sioux City and Omaha. There are a number of breeders who raise purebred stock for sale and a great many animals are sold out of the county.

Almost every farmer raises sufficient hogs for his own use and has a surplus for sale. Some of the hogs raised and fed are sold locally, but a large number are shipped in carload lots to outside markets. Hog raising in the county is one of the most important industries and brings an income probably larger than that from any other single source.

The dairy industry has increased during recent years. Milk cows are kept in small numbers on the average farm and in larger herds on the farms devoted chiefly to dairying. Favorite breeds are the Jersey and Holsteins. Creameries

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have been established and are in operation at Tipton, West Branch and Massillon. There is also considerable sale of cream to outside markets from nearly every town in the county.

A few years ago Cedar county was among the leading horse breeding sections of the state and the industry provided a considerable income on the farms. At present only a few draft animals are raised for local sale and home use.

Sheep are raised to some extent and the total pounds of wool clipped in 1920 was considerable.

Poultry raising is an important industry and on practically every farm the sale of poultry and poultry products provides a rather considerable income. The chickens and eggs are sold to merchants and produce men and some are utilized to supply the home demand, while a large portion are shipped to outside markets.

VALUE AND CONDITION OF CEDAR COUNTY LAND

The value of the land in Cedar county is quite variable, depending upon the location with reference to towns and railroad facilities, the improvements on the farm and general soil conditions. The average price of farm land is about $250 per acre. The range in selling price varies from $150 to $500 per acre. Much of the land is well improved and productive and will command the higher prices. Only a very few areas in the county are low in market value.

The yields of the general farm crops grown in Cedar county are usually quite satisfactory, but proper methods of soil treatment would undoubtedly bring about increases and thus insure more profitable returns from the land. The particular treatments which are needed vary somewhat, depending upon the particular soil conditions or the characteristics of the individual type. The needs of individual soil types will be taken up more at length in a later section of this report.

Drainage is important on some of the soil types in the county and should be provided in all cases where the soils are too wet. Tiling may be the only treatment needed to make some of the soils in the county quite satisfactorily productive and in general it may be said that if the drainage is inadequate no other soil treatment will prove effective.

The organic matter content of the soils of the county is not large and applications of farm manure bring about large increases in crop yields in practically all cases. The use of leguminous green manure crops may be needed in some instances to supplement farm manure or to take the place of that material. The use of legumes is very important on all the soils of the county if the nitrogen content is to be kept up.

Practically all the soils in the county are acid and applications of lime are needed in order to bring about the best growth of all farm crops, and particularly of legumes. Every soil in the county should be tested for acidity or lime requirement.

The phosphorus content of the soils of Cedar county is rather low and phosphorus fertilizers will be needed in the near future even if they do not prove of value at the present time. There are indications, however, that these materials may yield profitable crop increases on many of the soils of the county now. Experiments which are now under way in the county are testing the need of

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phosphorus on the main soil types and they are planned to determine also the relative value of the various phosphorus fertilizers. These tests have not been under way long enough to permit of definite conclusions and for the present it can merely be urged that farmers test the use of phosphorus fertilizers on their own soils, using both acid phosphate and rock phosphate and thus determine for their own conditions which material can be used most profitably.

Erosion occurs to some extent in the county and in those instances where the soil is badly washed some method of stopping the injurious action should be adopted.

THE GEOLOGY OF CEDAR COUNTY

All of the original bedrock material underlying the soils of Cedar county has been buried so deeply by the glacial deposits and loessial covering that it exerts no effect whatever on the soil conditions.

At least twice during the glacial age, great glaciers swept down from the north and upon their retreat each left behind an enormous mass of glacial drift, or till, spread over the entire surface of the land. The earlier glacier, known as the Kansan, covered the entire surface of the county, very largely obliterating all the earlier topographic features. Hence the depth of this drift layer is extremely variable, ranging from a few feet to many feet in different parts of the county, and varying considerably even within comparatively small areas. This Kansan drift material is typically a blue clay when not exposed to the weather; when oxidized or weathered it becomes a bright yellow to deep reddish-brown. Pockets of sand and gravel occur and boulders are frequently found. Occasionally this drift deposit is exposed in very small areas or appears within the three-foot section. Thus in the case of the Lindley silt loam, the subsoil is derived from the Kansan drift material. In general, the Kansan drift deposit has been very deeply buried under a subsequent glacial deposit or under a still later deposition of wind-carried material or loess.

The second glacier which invaded the county is known as the Iowan. It advanced from the west in two bodies and upon its retreat left behind two deposits of drift material, one extending from the Johnson and Linn county lines along the left bank of the Cedar river to Cedar Bluff, and then east in a constantly narrowing wedge to within a few miles of Tipton. The larger area extends across the northern townships and covers most of the area lying north of the main line of the Chicago and Northwestern Railroad. Thruout these areas the surface soil is predominantly of a drift origin, being derived from the Iowan glaciation. There are areas of loess, however, even in these portions of the county and the greater part of the surface soils of the county are of loessial origin.

At some period following the glacial age, when climatic conditions were very different than at present, a deposit of wind blown material known as loess was made over most of the surface of the county. Undoubtedly this covering of loess was originally very deep and in many instances is yet, the underlying drift material of the Kansan or Iowan glaciation being buried deeply by a thick mantle of loess. In some instances, however, the loess covering has been washed away

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to such an extent that the drift is encountered within the three-foot section. On the boundary between the Iowan drift plain and the earlier Kansan drift plain area, there are long rounded hills extending in a northwest-southeast direction. These hills are often referred to as *pahas*. In the areas in the vicinity of Cedar Bluff and Rochester these hills are covered with a fine sand known as the Knox fine sand. A rather considerable area of this type occurs south of Rochester along the Cedar river.

In its unweathered condition loess is an even grained material composed largely of silt. It ranges in color from a light grayish-brown to a yellowish brown. Under prairie conditions, abundant plant growth and the large plant residues resulting from this growth have led to the formation of dark colored soils. Where the loess has been weathered under forested conditions, organic matter has not accumulated to such an extent and the soils are lighter in color. Under these conditions also there has been more erosion and more leaching, owing to the fact that the topography of the wooded soils is more rolling. The prairie soils on the other hand are characterized by a rather level topography and hence there has been less washing away of valuable materials and no erosion. The soils of the Clinton and Knox series are derived from the loess weathered under forested conditions, while the Tama and Muscatine soils are developed under the prairie conditions.

The terrace and bottomland types in the county are not extensive and they are derived mainly from the loessial soils of the uplands. There are, however, some admixtures with glacial material which has been carried down from the upland by erosion and deposited by the streams.

PHYSIOGRAPHY AND DRAINAGE

The uplands of Cedar county consist mainly of a broad loess covered plain, the original surface of which has been modified to some extent by erosion. The topography of these uplands is generally undulating to smoothly rolling. This is the characteristic topography thruout the greater part of Inland, Fairfield, Red Oak and Springdale townships, the southern parts of Sugar Creek and Gower townships, and the northwestern part of Center township. Near Sunbury and Durant the upland plain still retains much of its original surface. Along both sides of the Cedar river and along some of the larger streams, erosion has been active and the topographic features include steep hills with rounded narrow areas between. This rougher country along the streams extends from one to two miles back from the stream courses and merges with the smoother topographic features of the uplands.

In the northern townships, north of the Chicago and Northwestern Railroad, where the Iowan drift plain is developed, the topography is somewhat different. Here there is a succession of high, smoothly rolling hills. These are called *pahas* and extend in a general northwest-southeast direction across the county and are separated by level to undulating, low upland areas.

Second bottoms or terraces are developed along the Cedar river from Cedar Bluff north to the Jones county line and from Rochester south to the Muscatine county line. A few isolated areas occur along the west side of the Wapsipinicon river north of Massillon. These terraces rarely exceed a half mile

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in width and are level to gently sloping. First bottomlands occur along practically all streams of the county and they are level.

The drainage of the county is accomplished mainly by the Cedar river which flows diagonally across the southwestern quarter of the county. From the Johnson county line to a point west of Buchanan and from Rochester south to the Muscatine county line the flood plain of the stream varies from a quarter of a mile to a mile in width, and is 50 to 100 feet below the adjoining uplands. On the west side of the river the uplands rise abruptly from the stream and are from 90 to 100 feet above the valley, while on the east the slopes are not so steep and the uplands are 15 to 20 feet lower. From a point where the Chicago, Rock Island and Pacific Railroad crosses the river west of Buchanan southeast to Rochester, the river cuts thru a narrow gorge from 100 to 140 feet deep, in many places thru limestone deposits. Sugar creek, Crooked creek, Rock Run creek and Clear creek are the most important tributaries and drain large areas thruout the central townships. A small area in the northeastern part of the county is drained by the Wapsipinicon river and its tributaries. These streams

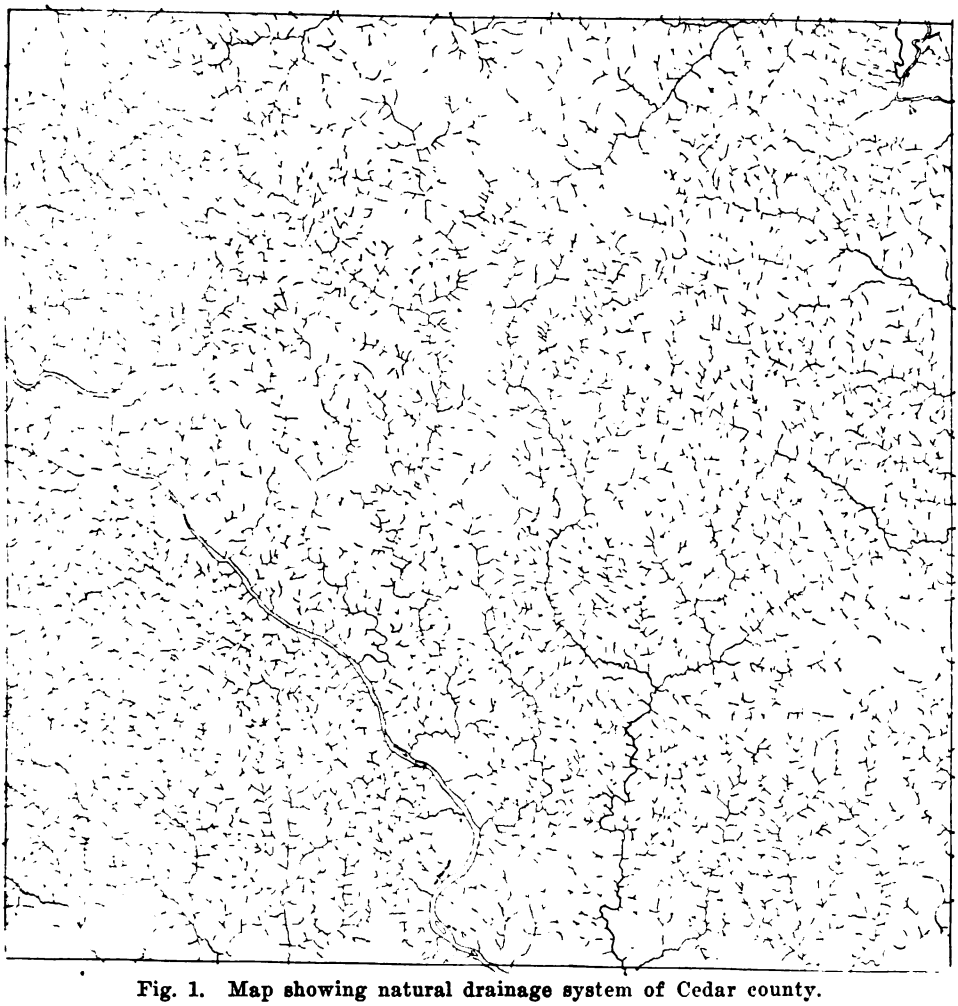

Fig. 1. Map showing natural drainage system of Cedar county.

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with their tributaries and many intermittent drainageways extend to practically all parts of the upland and the general drainage system of the county is quite adequate.

The accompanying map shows the very extensive and complete drainage system of the county. There are few areas in the uplands where the topography is flat and drainage is inadequate. The bottomlands are, of course, subject to overflow and many of them are too wet for the production of cultivated crops. The installation of tile may prove of value in some cases and wherever the moisture conditions are excessive, tiling would prove of value. In some of the rougher sections of the county drainage is excessive or at least the surface drainage is so extensive that serious washing occurs and in some of the soils erosion is an important factor and may reduce considerably the crop production.

THE SOILS OF CEDAR COUNTY

The soils of Cedar county are grouped into four classes according to their origin and location, drift soils, loess soils, terrace soils and swamp and bottomland soils. Drift soils are formed from materials carried by glaciers and deposited on the surface of the land when the glacier retreated. They are extremely variable in composition and contain pebbles and frequently boulders. Loess soils are fine dustlike deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by decreases in the volume of the streams which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low poorly drained areas or along streams and they are subject to more or less frequent overflow. The extent and occurrence of these four groups of soils in Cedar county are shown in table II.

Over three-fourths of the total area of the county, 81.5 percent, is covered by loess soils, the upland area thruout the major portion of the central and southern parts of the county being in the loess area. The drift soils are much smaller in extent, covering 11.3 percent of the total area of the county and occurring mainly in the northeastern portion of the county and in the central western part. The terrace soils are very minor in area, covering only 1.3 percent of the total area of the county. Swamp and bottomland soils are more extensive, covering 6.0 percent of the total area of the county.

There are 14 individual soil types in the county and these, together with the colluvial phase of the Wabash silt loam and the area of meadow, make a total of 16 separate soil areas. There are three drift soils, five loess types, four

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN CEDAR COUNTY

Soil group	Acres	Percent of total area of county
Drift soils	41,408	11.3
Loess soils	297,664	81.5
Terrace soils	3,904	1.2
Swamp and bottomland soils	21,824	6.0
Total	364,800	....

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TABLE III. AREAS OF DIFFERENT SOIL TYPES IN CEDAR COUNTY, IOWA

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
83	Carrington silt loam	39,424	10.8
32	Lindley silt loam	1,088	0.3
85	Clyde silty clay loam	896	0.2
	LOESS SOILS		
30	Muscatine silt loam	108,608	29.8
120	Tama silt loam	96,000	26.3
80	Clinton silt loam	88,448	24.2
33	Knox fine sand	4,352	1.1
154	Scott silt loam	256	0.1
	TERRACE SOILS		
36	Buckner silt loam	1,664	0.5
46	Buckner fine sand	1,280	0.4
45	Buckner fine sandy loam	704	0.2
42	Calhoun silt loam	256	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	15,616)	
26a	Wabash silt loam (colluvial phase)	2,304)	4.9
20	Meadow	2,752	0.8
48	Wabash silty clay loam	1,152	0.3
	Total	364,800	....

terrace soils and four areas of swamp and bottomland. These various soil types are distinguished on the basis of certain characteristics which are described in the appendix to this report and the names denote certain group characteristics. The areas of the various soil types in the county are given in table III.

The Muscatine silt loam is the largest individual soil type, covering over one-fourth of the county, 29.8 percent. It is also the largest loess type. The Tama silt loam is the second largest type, and the second loess soil in area, covering 26.3 percent of the county. The Clinton silt loam is slightly smaller than the Tama, covering 24.2 percent of the county. The other two loess soils are minor in extent, the Knox fine sand covering 1.1 percent and the Scott silt loam 0.1 percent of the county. The Carrington silt loam is the most extensive drift type and is the fourth largest soil area, covering 10.8 percent of the total area of the county. The Lindley silt loam and the Clyde silty clay loam are small in area, covering only 0.3 and 0.2 percent of the total area of the county. The terrace soils are all minor in area, the Buckner silt loam, the largest, covering only 0.5 percent of the county. The other types, the Buckner fine sand, the Buckner fine sandy loam, and the Calhoun silt loam, cover only 0.4, 0.2 and 0.1 percent of the county, respectively. The Wabash silt loam is the largest bottomland type and it is the fifth largest soil type in the county. Together with the colluvial phase, which is minor in area, it covers 4.9 percent of the county. The areas of meadow and Wabash silty clay loam are both small in extent, covering less than one percent of the county.

The upland soils are in the main gently undulating to rolling and this is the characteristic topography of the Tama and Clinton soils of the loessial area and of the Carrington silt loam of the drift area. The Muscatine silt loam, the most extensive type in the county, has a more level topography, however, altho

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in some parts it is gently rolling. The drainage condition in this type is not as satisfactory as that of the other important upland soils. The Clyde silty clay loam of the drift upland and the Scott silt loam of the loessial upland both occur in level to depressed areas in the uplands and are poorly drained. The Knox fine sand varies from undulating to rather strongly rolling and the Lindley silt loam is developed along the steeper slopes to the streams and has a rolling to strongly rolling topography. The Clinton silt loam in some areas is strongly rolling to rough and broken, altho in general the type has a more smoothly rolling surface. The terrace types are all rather level in area and the swamp and bottomland soils are likewise level to depressed. The bottomland types are in general poorly drained, but the terrace soils, with the exception of the Calhoun silt loam, are not in need of drainage. The bottomland types, of course, are subject to overflow and may need not only tiling but protection from overflow.

THE FERTILITY IN CEDAR COUNTY SOILS

Samples were taken for analyses from each of the soil areas in the county except the Lindley silt loam, the Knox fine sand and the area of meadow. The Lindley silt loam and the areas of meadow were not sampled, owing to the extreme variation in the soil conditions and the fact that the soils are of very little significance agriculturally and both are small in total area. The Knox fine sand was not sampled, as it is minor in extent and very much the same as the fine sands of the same type which have been analyzed many times in other counties. It is very low in organic matter and plant food and its needs are very readily determined without the making of analyses. All samplings were made with the greatest care that the samples should be representative of the particular soil types and that variations due to local conditions or previous treatment should be eliminated. Samples were drawn at three depths, 0-6 2/3", 6 2/3—20" and 20—40", representing the surface soil, the subsurface soil and the subsoil respectively.

Analyses were made in all cases for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The phosphorus, nitrogen and carbon determinations were made according to the official methods, and the Truog qualitative method was followed for the limestone requirement determinations. The figures given in the tables are the averages from the results of duplicate determinations on all samples of each type and they represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is quite variable, ranging from 1,037 pounds in the Buckner fine sand to 1,886 pounds per acre in the Clyde silty clay loam. There is no relationship apparent between the phosphorus content of the soils and the various soil groups. In fact, the variations are quite as large between the types within groups as they are between the various groups. Even the bottomland soils on the average do not show any considerable variation from the average phosphorus content of the other

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TABLE IV. PLANT FOOD IN CEDAR COUNTY, IOWA, SOILS
Pounds per acre of two million pounds of surface soil (0"—6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
83	Carrington silt loam	1,049	3,380	41,496	0	5,500
85	Clyde silty clay loam	1,886	8,620	104,559	0	5,000
	LOESS SOILS					
30	Muscatine silt loam	1,372	4,266	50,905	0	6,000
120	Tama silt loam	1,239	4,253	51,378	0	5,666
80	Clinton silt loam	1,048	2,120	24,843	0	2,000
154	Scott silt loam	1,872	4,920	57,047	0	6,000
	TERRACE SOILS					
36	Buckner silt loam	1,764	4,860	65,356	0	7,000
46	Buckner fine sand	1,037	600	12,831	0	3,000
45	Buckner fine sandy loam	1,401	2,800	29,320	0	7,000
42	Calhoun silt loam	1,387	3,440	38,493	0	4,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,064	3,780	40,840	0	2,000
26a	Wabash silt loam (colluvial phase)	1,266	3,820	41,769	0	2,000
48	Wabash silty clay loam	1,401	4,500	53,508	0	2,000

soil groups, altho ordinarily bottomland types are apt to be better supplied with this constituent owing to the fact that they have been cultivated to a smaller extent and there has been less removal of this constituent. There does seem to be some relation, however, between the various soil series and soil types and the phosphorus content. Thus the Muscatine and Tama soils are better supplied than the Clinton, and the Clyde soil contains more phosphorus than the Carrington. The Scott silt loam is much higher, likewise, than the other loess types. These variations are due mainly to the characteristics which serve to distinguish these soil series. The topographic position of the Clyde and Scott soils might be expected to indicate a higher plant food content than that present in the upland types in the same groups where the topography is rolling. Similarly the characteristics which serve to distinguish the Clinton soils from the Tama and Muscatine would account for a lower phosphorus content.

Some comparisons are possible from the standpoint of the soil types. In the upland soils there are only individual soils from each series but in the terraces and bottoms there are several types of the Buckner and Wabash series. From the analyses of these types it is apparent that the fine sand of the Buckner series is lower in phosphorus than the fine sandy loam and the latter type is much lower than the silt loam. The silt loam of the Wabash series is lower than the colluvial phase of the same type and that in turn is lower than the silty clay loam. Thus there is evidenced a rather definite relation between the soil texture and the phosphorus content and sandy soils and those of light texture in the same series are apparently lower in phosphorus content than soils of a heavier texture.

In general, table IV shows that the phosphorus supply of the soils of Cedar county is very low in many cases and phosphorus fertilizers will certainly be needed in the near future if satisfactory crop yields are to be secured. Furthermore, there are undoubtedly many cases where phosphorus fertilizers would prove of value at the present time. Even if they do not give large returns now, phosphorus must be taken into account in planning systems of

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permanent fertility. When the total supply of phosphorus is low, as it is in many cases in this county, it is rather safe to conclude that the supply of available phosphorus will be insufficient for the best crop growth. Even where there is a large total amount of phosphorus present, no assurance can be given that sufficient will be produced in an available form to keep crops supplied, but if the general soil conditions are satisfactory the production of available phosphorus from a large store in the soil should be adequate to meet crop demands. There are many instances when phosphorus fertilizers give returns on soils which are apparently fairly well supplied with the element. In such cases the beneficial effect is due to the addition of available phosphorus and indicates that the production of available phosphorus in the soil is too slow. Individual farmers are urged to test phosphorus fertilizers on small areas on their own farms and thus determine for their own conditions whether or not these materials are profitable.

The soils of the county are even more variable in nitrogen than they are in phosphorus. The supply of this constituent ranges from 600 pounds in the Buckner fine sand up to 8,620 pounds in the Clyde silty clay loam. With the exception of the Buckner fine sand, however, the nitrogen content is not strikingly deficient in any of the soils, but neither is it very high and on the average, leaving out of account the two types mentioned above, the supply of nitrogen is just fair. Again, as was noted in the case of phosphorus, there is no relation apparent between the various soil groups, and the upland types seem to be about as well supplied with this constituent as the bottomland soils, on the average. The same is true of the terrace soils with the exception of the Buckner fine sand. There does seem to be some relation, however, between the soil series and the soil texture and the nitrogen supply. Thus the Muscatine and Tama soils are higher than the Clinton, and the Scott series is higher than the Muscatine and Tama. The Clyde soil is very much higher than the Carrington. These differences are very much the same as were indicated in the case of phosphorus and are undoubtedly due to certain characteristics which serve to distinguish the soil series. Probably the topographic position of the soil is quite as important as any other characteristic in determining the nitrogen content of the soil. Thus it might be expected that the soils of the Scott and Clyde series would be somewhat higher in plant food constituents than the corresponding upland soils of the same groups.

The soil texture certainly has some influence on the plant food content and while it is impossible to make any comparisons in the case of the upland soils, it is apparent from the terrace and bottomland types that soils of a light texture are lower in nitrogen than those which are heavier in texture. Thus the Buckner fine sand is very low in nitrogen. The fine sandy loam is somewhat higher but very much less in turn than the silt loam of the same series. Similarly the Wabash silt loam is lower in nitrogen than the Wabash silty clay loam and slightly lower than the colluvial phase of the same type. It seems, therefore, that the soil texture undoubtedly exerts an important effect on the nitrogen content of the soil.

Inasmuch as the soils of the county in general are only fairly well supplied with nitrogen, this element must not be neglected in planning systems of per-

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manent soil fertility, and in some instances the addition of nitrogenous materials would undoubtedly prove profitable at the present time. Farm manure is probably the most important natural fertilizing material for soils and it returns a large part of the nitrogen removed from the soil by the crops grown. Similarly the proper utilization of crop residues will cut down the losses of nitrogen from the soil and both these materials may therefore be considered in part at least as nitrogenous fertilizers.

But the nitrogen content of soils cannot be kept up indefinitely with these materials alone and neither can soils low in nitrogen be built up in this constituent by the use of such materials. Leguminous crops used as green manures are the cheapest and most satisfactory nitrogenous fertilizers. When well inoculated, legumes are able to take part of their nitrogen from the atmosphere and when such crops are turned under in the soil they add a considerable amount of nitrogen to the soil. The actual amount of this element added depends upon several factors, such as the completeness of inoculation, the character of the crop grown and the nitrogen content of the soil. It is generally believed that in the case of clover, the nitrogen content of the tops is equal to that taken from the atmosphere and hence with this crop the amount of nitrogen added to the soil is determined very largely by the size of the crop. The practice of green manuring with legumes is one of considerable value in maintaining the nitrogen supply and it is especially valuable for building up the nitrogen content of soils which are low in this constituent.

The addition of farm manure, crop residues and leguminous green manures to soils not only increases and maintains the nitrogen supply in the soil, but also permits of the maintenance of the organic matter supply. Thus there is a distinct relation between the maintenance of nitrogen and organic matter in soils and similarly there is a very definite relation usually evidenced between the nitrogen and organic carbon present in soils. The color of the soil indicates quite definitely the content of these constituents. Soils which are black in color are generally high in organic carbon and nitrogen, while those which are light in color are low in these constituents.

The color of soils is one of the important characteristics determining in part the series in which they are classed and there is usually also a relation between the color of soils and their texture. Hence it would be expected that there would be a relation between the organic carbon and the nitrogen content of soils and the soil series and soil texture. The relations which have just been considered from the nitrogen standpoint very largely hold true for the organic carbon and the series which are low in nitrogen are low in organic carbon and, again, it is evident that the topographic condition which serves to distinguish the particular soil series bears an important relation to the organic matter content of the soil. The effect of soil texture is also evidenced and fine textured types are much lower in organic matter than those which are heavier in texture. In fact the relations from the organic carbon standpoint are much more striking than they were in the case of nitrogen.

The actual relation which exists between the nitrogen and organic carbon content of soils provides some evidence of the rate at which plant food is being made available. In practically all cases the relation between these constituents

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in the soils of Cedar county is quite satisfactory and with the exception of one or two types it would seem that plant food should be produced sufficiently rapidly to keep crops supplied. As a matter of fact, however, applications of farm manure have been found to be of large value on many of these soils and even on those types which are better supplied with organic matter. Hence it would seem that the stimulation of available plant food production is very desirable on many of these soils in spite of the apparently satisfactory relation between the nitrogen and organic carbon. Farm manure is a valuable fertilizing material on the soils of the county, however, not entirely because it stimulates available plant food production, but also because it serves to keep up the supply of organic carbon. The soils of the county with one or two exceptions are not particularly high in this constituent and the organic matter supply must be maintained if crop yields are to prove satisfactory. Farm manure is the most valuable material for use in supplying the need of organic matter in soils. Crop residues should also be utilized to keep up the supply of this material and where sufficient of these materials are available for use, no difficulty should be experienced in building up and keeping up the organic matter in soils. In many instances, however, the supply of farm manure is inadequate and if the content of organic carbon is to be increased, some other source of organic matter must be used. In such cases leguminous green manures are the most desirable materials owing to the fact that they supply nitrogen as well as organic matter.

There is no inorganic carbon content in any of the surface soils of the county and hence it would be expected that the soils would show a rather considerable acidity or limestone requirement. This is actually the case and it is apparent that lime will need to be used on all the soils of the county if they are to be made satisfactorily productive, particularly for legumes. The figures given in table IV indicate the limestone requirement of the various soil types, but these figures should not be interpreted too broadly. Soils vary widely in acidity and need of lime and even the average of many analyses would not indicate accurately the limestone requirement of any particular field. Soils of the same type may show a varying need for lime and even in the same field there may be considerable variation. Hence it is very important that every soil be tested for lime requirement before that material is used. Farmers may make such tests themselves or they may send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge. Legumes are particularly sensitive to acidity in soils and if these crops are to be grown satisfactorily in Cedar county it is very important that the soils be tested and that lime be applied as shown to be necessary according to the tests.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre.

Unless there is a very large amount of plant food constituents present in the lower soil layers, there is very little effect upon the fertility of the soil and the analyses of the surface soils usually indicate quite clearly the plant food supply of the soil and indirectly its crop producing power. The lower soil layers in

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TABLE V. PLANT FOOD IN CEDAR COUNTY, IOWA, SOILS

Pounds per acre of two million pounds of subsurface soil (6 2-3"—20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
83	Carrington silt loam	1,548	4,460	51,416	0	4,500
85	Clyde silty clay loam	2,640	9,800	112,476	0	2,000
	LOESS SOILS					
30	Muscatine silt loam	1,939	4,826	45,840	0	6,000
120	Tama silt loam	1,956	5,733	69,196	0	6,000
80	Clinton silt loam	1,346	2,100	21,840	0	2,000
154	Scott silt loam	2,074	3,920	43,680	0	8,000
	TERRACE SOILS					
36	Buckner silt loam	3,362	7,280	106,797	0	6,000
46	Buckner fine sand	1,966	1,200	18,018	0	2,000
45	Buckner fine sandy loam	3,582	3,560	35,162	0	2,000
42	Calhoun silt loam	2,210	4,720	53,289	0	4,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,208	7,320	75,894	0	2,000
26a	Wabash silt loam (colluvial phase)	2,478	7,000	86,258	0	2,000
48	Wabash silty clay loam	3,906	8,320	101,337	0	2,000

Cedar county are not high in any of the essential plant food constituents and hence the fertility of the soils will be influenced only very slightly by the different subsoil conditions. Therefore the analyses of the subsurface soils and subsoils in this county need not be considered in detail. It may merely be mentioned that the needs of the individual soils as indicated by the analyses of the surface soil are very largely confirmed by the results obtained from the analyses of the lower soil areas.

Phosphorus fertilizers will certainly be needed in the future and might be of large value at the present time. The supply of organic matter and nitrogen must be maintained in all cases and in several instances the soils must be built up in these constituents. Hence it is important that farm manure and crop residues be utilized as far as possible on the soils and leguminous green manures

TABLE VI. PLANT FOOD IN CEDAR COUNTY, IOWA, SOILS

Pounds per acre of six million pounds of subsoil (20"—40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirem'nt
	DRIFT SOILS					
83	Carrington silt loam	2,667	1,920	26,208	0	3,000
85	Clyde silty clay loam	3,555	9,960	99,899	1,740	Basic
	LOESS SOILS					
30	Muscatine silt loam	2,421	3,120	37,510	0	5,666
120	Tama silt loam	2,424	3,800	42,621	0	5,000
80	Clinton silt loam	2,789	1,830	16,380	0	2,500
154	Scott silt loam	2,586	2,520	27,027	0	4,000
	TERRACE SOILS					
36	Buckner silt loam	2,991	5,160	82,719	0	3,000
46	Buckner fine sand	2,061	960	16,871	0	2,000
45	Buckner fine sandy loam	4,728	2,880	24,733	0	2,000
42	Calhoun silt loam	2,991	3,540	34,398	0	5,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	3,273	9,480	110,565	0	2,000
26a	Wabash silt loam (colluvial phase)	3,597	18,240	253,890	0	2,000
48	Wabash silty clay loam	8,931	9,120	126,126	0	2,000

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might frequently be employed with profit in addition to these materials. The soils are all acid in reaction and lime must be applied for the best crop growth. The soils should be tested at regular intervals at least once in a four year rotation and the amount of lime needed determined. Only in one case is there any lime in the subsoil in the county and this is a small amount and there would be practically no effect on the surface needs of the soil. Farmers in the county who are planning on growing legumes should see to it that their soils contain the proper amount of lime or they may experience considerable difficulty in obtaining satisfactory legume growth.

GREENHOUSE EXPERIMENTS

A greenhouse experiment was carried out on the Tama silt loam, one of the important soil types in Cedar county, and the results of experiments on the Muscatine silt loam from Clinton county, the Tama silt loam from Black Hawk county and the Carrington silt loam from Linn county are also included in this report. These experiments are all planned to secure indications of the fertilizer needs of the soils and to learn the value of the application of certain common fertilizing materials. The experiments on the typical soils from Clinton, Black Hawk and Linn counties are included, as the soil types are the same as those predominating in Cedar county, and the results secured indicate quite definitely the needs of the same soil types in this county.

The plan of all these experiments was very much the same. The treatments used were manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. The size of the applications was the same as is used in the field tests and hence the results of these greenhouse experiments may be considered to indicate the results which may be secured in the field. Manure was applied at the rate of eight tons per acre. Lime was added in sufficient amounts to neutralize the acidity of the soil and two tons additional were supplied in order to put the soil in the best condition for crop growth. Rock phosphate was applied at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and the standard 2-8-2 brand of a complete fertilizer at the rate of 300 pounds per acre.

Wheat and clover were grown in all the pots, clover being seeded about one month after the wheat was up. In the experiment on the Tama silt loam from Cedar county, only the clover yields are given in the table, as the wheat yields were not secured.

RESULTS ON TAMA SILT LOAM

The results of the experiment on the Tama silt loam from this county are given in table VII, the figures being the averages of the yields on the duplicate pots, only the green weight of the clover being secured. In all the other experiments the dry weights were taken.

Manure exerted a large effect on the clover crop, increasing the yield tenfold. The application of lime along with manure brought about a further increase. Rock phosphate showed no effect but the acid phosphate and the complete commercial fertilizer both gave large increases in the clover, the commercial fertilizer showing up slightly better than the acid phosphate. Apparently the Tama silt

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TABLE VII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, CEDAR COUNTY

Pot No.	Treatment	Green weight clover in grams
1	Check	4.53
2	Manure	43.09
3	Manure+Lime	58.96
4	Manure+Lime+Rock phosphate	58.96
5	Manure+Lime+Acid phosphate	106.59
6	Manure+Lime+Complete commercial fertilizer	111.13

loam will respond very definitely to the application of manure, and lime along with manure will increase still further the growth of a legume. Phosphorus fertilizers may apparently be used with value in some cases, the acid phosphate showing up better than the rock phosphate in this particular instance. Definite comparisons cannot be made between these two materials from the small amount of data available and neither can it be said definitely that the complete commercial fertilizer should never be used. This experiment indicates larger value from the phosphates, but there may be instances where the complete fertilizer would prove more desirable. The results may be considered to indicate very definitely, however, the possible value of the use of a phosphorus fertilizer on this soil.

The results of the experiment on the Tama silt loam from Black Hawk county are given in table VIII.

The application of manure had little effect on the wheat crop, but again, as was noted in the experiment on this same soil from Cedar county, the clover crop was increased enormously. Lime showed little effect on the wheat but again brought about a large increase in the clover. This would be expected inas-

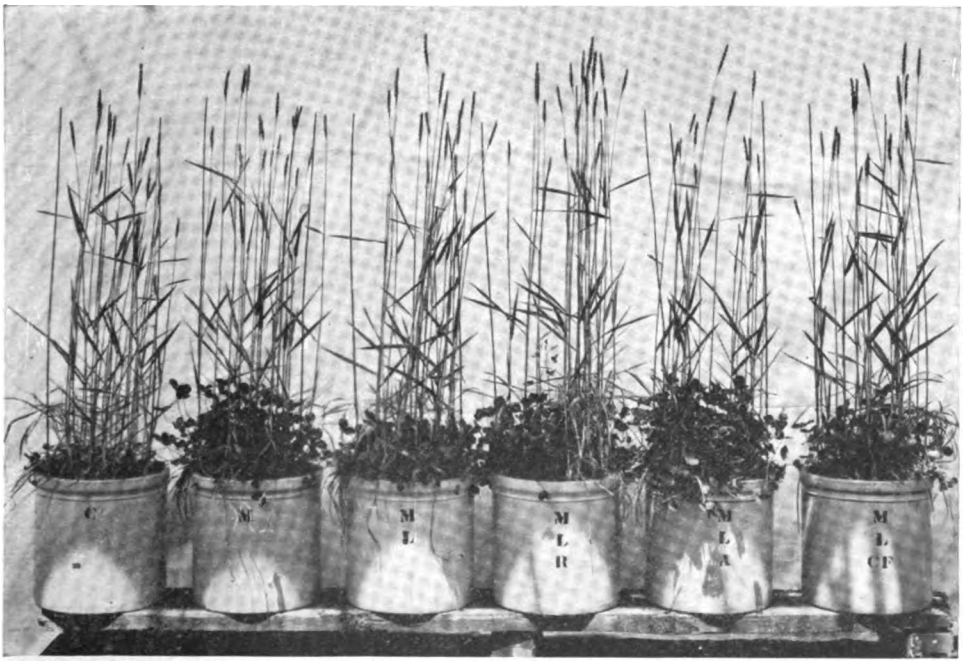

Fig. 2. Wheat and clover on Tama silt loam, Black Hawk county.

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TABLE VIII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+Lime	12.86	51.5
4	Manure+Lime+Rock phosphate	14.03	57.0
5	Manure+Lime+Acid phosphate	12.72	64.5
6	Manure+Lime+Complete commercial fertilizer	13.67	59.5

much as the legumes are so much more sensitive to a lack of lime than are the grain crops. Rock phosphate with manure and lime increased the wheat yield and had a slight effect on the clover crop. Acid phosphate with manure had little effect on the wheat but brought about a large increase in the clover and the complete commercial fertilizer showed a smaller effect than the acid phosphate in the case of clover but a slightly larger influence on the wheat. These results confirm those secured on the same soil type in Cedar county and indicate very definitely the large value from the application of manure to this soil, the need of lime to secure the best growth of legumes and the possible beneficial effect of the application of phosphorus fertilizers.

RESULTS ON MUSCATINE SILT LOAM (CLINTON COUNTY)

The results on the Muscatine silt loam from Clinton county are given in table IX.

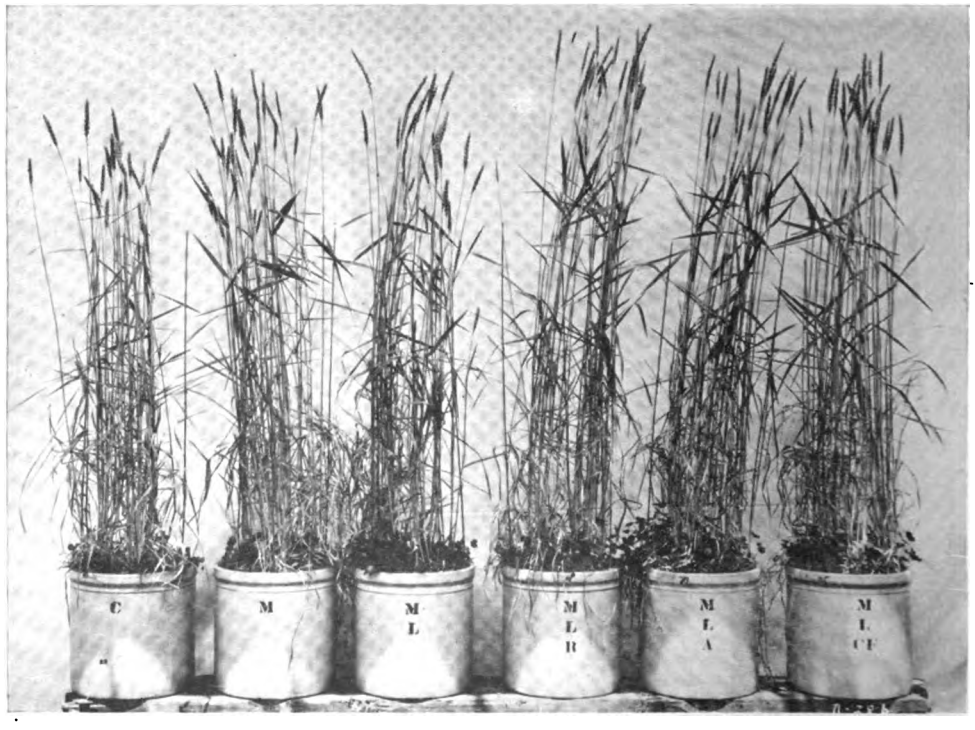

Fig. 3. Greenhouse experiment with wheat and clover on Muscatine silt loam in Clinton county.

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TABLE IX. GREENHOUSE EXPERIMENT, MUSCATINE SILT LOAM, CLINTON COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	22.75	35.5
2	Manure	25.97	33.0
3	Manure+Lime	30.42	45.0
4	Manure+Lime+Rock phosphate	28.55	51.5
5	Manure+Lime+Acid phosphate	31.42	63.0
6	Manure+Lime+Complete commercial fertilizer	29.02	58.5

The application of manure brought about a beneficial influence on the wheat and the use of lime in addition to manure still further increased this grain crop. The clover was not influenced to any extent by the manure, but the lime addition gave a large increase in the yield. The phosphate fertilizers and the complete commercial fertilizer had no effect on the wheat except in the case of the acid phosphate, where a small influence was noted, but these materials all exerted distinctly beneficial effects on the clover crop. The acid phosphate proved particularly valuable in connection with this crop, showing up to better advantage than the complete commercial fertilizer. The latter, however, gave better results than the rock phosphate. Apparently the needs of this soil type include the application of manure, the use of lime as necessary to remedy acid conditions and the application of phosphate fertilizers. Further experiments must be conducted before it will be possible to reach any definite conclusion regarding the most profitable phosphate material for use in the county.

RESULTS ON CARRINGTON SILT LOAM (LINN COUNTY)

The results of the experiment on the Carrington silt loam from Linn county are given in table X.

The application of manure brought about a large increase in both the wheat and the clover crop, the effect being particularly noticeable on the clover. When lime was applied in addition to the manure, still further increases were noted, a larger effect being apparent again in the case of the clover. Rock phosphate, acid phosphate and the complete commercial fertilizer showed very little effect on the wheat crop, altho there is some evidence of value from the acid phosphate. In the case of the clover all three materials brought about distinct increases in crop yields, the acid phosphate giving the largest effect. It is evident that manure is a particularly valuable fertilizing material for use on this soil. Lime should be applied when the soil is acid and there are indications of value from the use of phosphorus fertilizers, particularly in the case of clover.

TABLE X. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	16.74	10.5
2	Manure	18.29	16.0
3	Manure+Lime	22.00	28.0
4	Manure+Lime+Rock phosphate	22.50	32.0
5	Manure+Lime+Acid phosphate	23.53	34.5
6	Manure+Lime+Complete commercial fertilizer	21.13	33.0

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Fig. 4. Wheat and clover on Carrington silt loam, Linn county.

These greenhouse experiments as a whole indicate that the Muscatine silt loam, the Tama silt loam and the Carrington silt loam, the three most extensive soil types in the county, will respond to applications of manure, this material bringing about large increases in crop yields in practically all cases. Lime should be used on these soils when they are acid if the best growth of legumes is to be secured. There are indications of value also from the use of phosphate fertilizers but the experiments are not complete enough to permit of the drawing of definite conclusions as to which material should be employed. The field experiments are planned to throw additional light on this point and farmers may secure further information by testing the materials on their own soils as has been suggested.

FIELD EXPERIMENTS

Field experiments have been under way in Cedar county for only a short time and it is impossible as yet to draw any conclusions from the results which have been secured. Experiments of this kind must be conducted for several years before the results can be considered in any way conclusive. The results of some field experiments in other counties on the same soil types which occur extensively in Cedar county will be included in this report, inasmuch as they undoubtedly indicate quite definitely the needs of these same soils in this county and give an indication of the profit which may be secured from the use of certain

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fertilizing materials. The results obtained from the fields just established in this county will be published later in a supplementary report. For the present recommendations must be based upon the laboratory and greenhouse experiments and the field tests on the same types from other counties and on the practical experience of farmers in the county. It might be noted here that the experience of many farmers confirms the results from the field experiments in other counties.

All the field experiments are planned with the idea of determining the relative value of various soil treatments and they are laid out on land which is entirely representative of the particular individual soil type which it is intended to study. All precautions are taken in the application of fertilizers and the harvesting of the crops to make it certain that accurate results are secured. The plots are permanently located by the installation of corner stakes and they are 1-10 of an acre in size, each plot being 156 feet, 6 inches, by 28 feet, and separated by a 7-foot border from the adjacent treated plots.

These fields include tests under the livestock and grain systems of farming. In the former manure is applied, while in the latter crop residues are utilized in place of manure. Other fertilizing materials tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. Manure is applied in all cases at the rate of 8 tons per acre once in a four-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is added at the rate of 2,000 pounds per acre once in the rotation, acid phosphate is used at the rate of 200 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer is added at the rate of 300 pounds per acre annually. Only the results on the livestock group of plots are given in this report, inasmuch as the crop residue plots have not been under way long enough to show any effect from the introduction of the residues.

THE LETTS FIELD

A field experiment has been under way for several years on the Muscatine silt loam in Muscatine county. This is located near Letts and is known as the Letts field. The results of this experiment to date are given in table XI.

The effect of manure shows up very definitely on the corn, oats and wheat crops. Very little evidence of its effect is noted in the case of clover and timothy. Lime in addition to manure gave some indications of value, par-

TABLE XI. FIELD EXPERIMENT, MUSCATINE SILT LOAM, MUSCATINE COUNTY
Letts Field

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Wheat bu. per acre 1920	Clover and timothy tons per acre 1921
1	Check	75.4	57.8	17.1	2.11
2	Manure	77.8	58.6	20.6	2.13
3	Manure+Lime	77.2	58.6	23.9	2.26
4	Manure+Lime+Rock phosphate	82.9	62.6	28.5	2.58
5	Manure+Lime+Acid phosphate	83.7	62.6	27.5	2.73
6	Manure+Lime+Complete commercial fertilizer.	84.8	67.4	31.2	2.76
7	Check	78.4	51.0	19.9	2.10

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ticularly in the case of wheat and clover. The application of rock phosphate, acid phosphate and a complete commercial fertilizer gave indications of value on all the crops in the rotation. The three materials gave very much the same results on the corn. The commercial fertilizer showed up the best on the other three crops in the rotation but the differences are not very large in any case. The acid phosphate and rock phosphate gave results so nearly alike that no choice can be made between them for this particular soil. The complete commercial fertilizer did not seem to be of large enough value on this soil to warrant its use in preference to the phosphate carriers. It is doubtful if the additional expense involved in the use of complete brands would be warranted.

THE BLUEGRASS FIELD

Another field experiment is being carried out on the Muscatine silt loam in Scott county. It is known as the Bluegrass field. The results secured to date on this field are given in table XII.

The results of this experiment very largely confirm those secured on the Letts field and they indicate quite definitely the value of the application of manure to the Muscatine silt loam in spite of the fact that this soil is very well supplied with organic matter and comparatively highly productive. The addition of manure brought about an increase in the yields of the various crops grown and this increase from the use of manure is shown very definitely in the case of the corn. The use of lime in addition to manure was of value in increasing crop yields and there are indications of profit from the use of phosphate fertilizers. It is of particular interest to note the beneficial effect of acid phosphate on the yield of wheat. This is a result which confirms much experience with the use of phosphates on wheat. The phosphates also showed value in the case of the other crops of the rotation. The corn yields for the first year of the experiment are not included in the table, as they were somewhat abnormal. It may be concluded from this experiment that the Muscatine silt loam will be particularly benefited by applications of manure, and lime when needed. Phosphate fertilizers might prove of value, but field tests must be carried out on individual farms to determine the particular phosphate carrier which should be used.

THE HUDSON FIELD

An experiment has been carried out on the Tama silt loam near Hudson in Black Hawk county. The results obtained on this soil type are included, inas-

TABLE XII. FIELD EXPERIMENT, MUSCATINE SILT LOAM, SCOTT COUNTY
Blue Grass Field—Series I

Plot No.	Treatment	Spring wheat bu. per acre 1919	Clover tons per acre 1920	Corn bu. per acre 1921
1	Check	11.2	1.57	54.7
2	Manure	12.4	1.92	57.8
3	Manure+Lime	13.3	2.37	66.1
4	Manure+Lime+Rock phosphate	13.1	2.35	67.5
5	Manure+Lime+Acid phosphate	18.9	2.37	63.5
6	Manure+Lime+Complete commercial fertilizer	14.4	2.35	64.0
7	Check	11.3	2.22	56.5

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TABLE XIII. FIELD EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY
Hudson Field

Plot No.	Treatment	Corn bu. per acre 1918	Oats bu. per acre 1919	Corn bu. per acre 1920
1	Check	45.8	47.6	53.2
2	Manure	49.3	54.7	62.8
3	Manure+Lime	54.4	59.2	67.4
4	Manure+Lime+Rock phosphate	56.5	64.9	73.3
5	Manure+Lime+Acid phosphate	57.4	62.2	73.3
6	Manure+Lime+Complete commercial fertilizer	58.5	57.5	72.4

much as results are directly applicable to the same soil type in Cedar county. Crop yields were not secured on these plots in 1921 owing to an oversight on the part of the cooperator, hence the table gives the yields for 1918, 1919 and 1920. The results of this experiment are given in table XIII.

The results given in the table indicate quite definitely the beneficial effects of manure, lime and phosphorus fertilizers on the Tama silt loam. Manure seems to be of particular value on this soil for corn and oats and it is interesting to note the beneficial effect of lime when applied along with manure, increases being secured in every case from the use of this material, which is not ordinarily expected to have any particular beneficial influence on corn and small grains. Apparently the improvement of the reaction of this soil is of considerable value from the crop production standpoint. Rock phosphate, acid phosphate and the complete commercial fertilizer all brought about beneficial effects on the crops grown. The differences between the effects of these various materials are too small to be conclusive, and indeed, they are somewhat variable on the same crop in different seasons. However, the results do indicate quite distinctly that phosphorus fertilizers may probably be used on this soil with beneficial effects at the present time. The results serve to emphasize the importance of testing phosphorus fertilizers on the individual farm.

THE SPRINGVILLE FIELD

An experiment is under way on the Carrington silt loam at the Springville field in Linn county. The results of this experiment to date are given in table XIV.

The yield of corn on the manure-lime plot in 1920 is not included, owing to its very evident abnormality and similarly, in 1921, the yield of oats on the manure plot is not included. A small ditch runs thru the manure-lime plot and af-

TABLE XIV. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY
Springville Field—Series I

Plot No.	Treatment	Clover tons per acre 1918	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921
1	Check	2.25	58.6	46.5	44.8
2	Manure	2.47	64.8	63.3	....
3	Manure+Lime	2.40	63.7	....	46.9
4	Manure+Lime+Rock phosphate	2.70	60.8	66.1	42.8
5	Manure+Lime+Acid phosphate	2.70	67.1	60.8	46.3
6	Manure+Lime+Complete commercial fertilizer	2.70	64.5	61.0	49.2
7	Check	1.65	60.0	51.9	36.9

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fects the yield on this and the manure plot. The results of this field experiment thus far indicate very definite value from the application of manure on the Carrington silt loam. It is the most valuable fertilizer for this soil and its application in liberal amounts is strongly to be recommended. The effect of the manure is evidenced on the character of the crop growth at all stages and the increased yields given in the tables often do not indicate adequately the variations which are noticed in the field. The addition of lime along with manure is needed when this soil is acid in order to secure the best growth of legumes.

The phosphate fertilizers seem to give indications of value on this soil type, there being, however, very little opportunity for a choice between the various materials. In some cases the acid phosphate seems to be preferable, while in others the rock phosphate shows up somewhat better. Again the complete commercial fertilizer gives larger effects than the other materials. In no case, however, is there sufficient difference in the yields secured to warrant a choice. It may merely be said that phosphorus fertilizers should be tested on this soil and that material employed which shows the most beneficial effect according to tests.

These field experiments as a whole indicate very distinctly the needs of three of the leading soil types in Cedar county, the Muscatine silt loam, the Tama silt loam and the Carrington silt loam. Later field experiments will yield much more definite information, but it may very safely be concluded at the present time that manure is a particularly valuable fertilizer for use on these soils, showing up large value particularly on the Tama silt loam. Lime is needed if the soils are acid and beneficial effects will undoubtedly be secured in many cases from the use of phosphorus fertilizers. It is urged that farmers test these materials on their own soils and if profitable increases are secured, then the same material may be applied to large areas with the assurance of profit.

THE NEEDS OF CEDAR COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The field experiments which are now under way in Cedar county will eventually yield results which will permit of rather definite conclusions regarding the fertilizer needs of the important soil types in the county. At the present time recommendations can be based only upon the laboratory and greenhouse tests and upon the results of the field experiments on the same soil types in other counties. The experience of many farmers confirms some of the observations made in these field tests. No recommendations regarding the treatment of individual soils in the county are made which are not based on actual farm experience and are therefore of proven value. Where definite recommendations are not possible, owing to the lack of practical tests, it is suggested that certain tests be made by individual farmers on their own soils. In this way the indications of value from the application of some fertilizer materials as shown by the laboratory and greenhouse tests may be checked up on the individual farm. Furthermore, the information which is secured will prove of consider-

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able value in the solution of the problem of the fertilization of the same soil type elsewhere. It is a comparatively simple matter to test the use of a fertilizer on the farm and the Soils Section of the Iowa Agricultural Experiment Station is ready to aid and advise.

LIMING

The soils of Cedar county are all acid and in need of lime. The acidity of the soils extends thruout the three foot section in practically every instance. There is only one type in the county which shows a basic reaction, even in the subsoil, and in that case the amount of lime present is small and with adequate drainage that particular type would very quickly be in need of lime.

The analyses given earlier in this report indicate the extent of acidity in the various soil types and it is apparent that considerable amounts of lime will need to be used in most cases to bring the soils back to a basic reaction. These analyses, however, should not be interpreted too broadly because of the fact that the acidity of soils is an extremely variable condition. Soil types will vary widely in lime requirement and even within relatively small areas there may be a considerable variation in the acidity developed in the soil. It has been found, for example, that in one field the soil may test differently in different parts of the field and this being true, it may readily be appreciated that the results of the analyses of the lime requirement of a soil type, even if based on the average of a large number of determinations, will not give figures which will show exactly how much lime must be applied to a particular field.

Every soil should be tested for acidity before lime is applied and then the proper amount may be used. If a test is not made there is danger of applying an insufficient amount of lime and this would mean that the best results from the application could not be secured. On the other hand, an excessive application might be made, which, while not injurious if limestone were employed, would prove less profitable than the use of the proper amount. Farmers may test their own soils for acidity but it will probably be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

Leguminous crops do not make their best growth in acid soils. Clover and alfalfa are particularly sensitive to acidity and if satisfactory yields of these crops are to be secured, lime must be used. Other farm crops also do not make as satisfactory growth under acid conditions as they do when the soil contains lime. Frequently corn and small grain crops show increases from the use of lime, and while these increases are not so large as in the case of the legumes, still they may be of considerable importance. The beneficial effect of lime on such crops may be due to the removal of acidity or to the stimulation of beneficial bacterial action and the greater production of available plant food. It may also be due to the indirect effect of a larger legume growth and consequently a greater addition of organic matter and nitrogen in the legume crop residues.

Lime may have some value in certain cases because of the effect on the physical condition of the soil, but in most cases its use is needed particularly to remedy acid conditions. If the soils of Cedar county are to be made properly productive

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and if their fertility is to be maintained permanently, they must all be tested and lime applied as shown to be necessary according to the tests. Furthermore, it will not be sufficient to test the soils once and make one application of lime. There is a continual removal of this material thru utilization by crops and washing away in the drainage water and hence one application of lime may last for only a brief period. If the soil is well drained, as it should be for satisfactory crop growth, there will be a continual removal of lime in the drainage water. The larger the crop growth the greater the removal of lime in the crop. Hence, the more satisfactory the soil conditions are made for crop growth the more necessary does it become that lime be applied regularly.

There are other factors which influence the disappearance of lime from soils. Soils light in texture will lose their lime more rapidly than heavier textured types. Leguminous crops will remove lime more rapidly. The physical condition of the limestone applied will determine to some extent the rapidity of the loss. The finer the division of the limestone, the more readily will it be leached out of the soil. The extent of acidity will also play a part in determining the time at which additional amounts of lime will be needed. If the soil is strongly acid the lime will be very rapidly used up in neutralizing the acidity. Taking all these considerations into account, it seems that soils should be tested at least once in a four-year rotation if the supply of lime is to be kept up.

The farmers of Cedar county may be assured that applications of lime to their soils will bring about large effects and will prove distinctly profitable. It is urged, therefore, that the soils of the county be tested at regular intervals and that lime be applied as necessary in order that the most satisfactory crops may be secured and the soils kept permanently productive. Further information regarding the use of lime on soils, losses by leaching and the effect on crops is given in bulletin 151 of the Iowa Agricultural Experiment Station. A list of companies from which the material may be secured and the cost of the same are given in circular 58.

MANURING

The soils of Cedar county do not contain any large amount of organic matter, except in the case of the Clyde silty clay loam, which is rather high in this constituent; in some instances the amount of organic matter present is quite low. The Buckner fine sand, for example, is low in organic carbon and the Clinton silt loam is rather poorly supplied with this material. The soils of the county in general contain only an average amount of organic matter and additions of fertilizer materials supplying organic matter are very desirable.

Manuring is undoubtedly one of the most important farm practices for the soils of Cedar county and the results secured indicate very definitely that it is a very valuable fertilizing material. No other fertilizer produces anything like the large effects on crop growth; in fact, other materials have small influence when manure is not applied also. Experiments indicate the large crop increases which are secured from the use of farm manure, and the practical experience of many farmers confirms the results of these experiments. It is not only the light textured, light colored types which respond to manure, but even the heavier, dark colored soils are made much more productive by the use

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of this material. Even the Muscatine silt loam and the Tama silt loam, which are apparently fairly well supplied with organic matter, yield much larger crops when farm manure is applied to them.

Soils are benefited by applications of manure because of the improved chemical, physical and bacteriological conditions. Manure contains a large part of the plant food which has been removed from the soil by the crops grown and utilized for feed and hence it returns to the soil considerable amounts of the various plant food constituents. In this way it lengthens the life of the soil or in other words, prolongs the time until any of the essential plant food constituents become deficient. The physical conditions of soils, whether light textured or heavy textured, are improved by applications of manure. Light soils are made less open and porous, less subject to losses by leaching and more retentive of moisture. Heavy soils are opened up and made less impervious and better aerated, and the removal of excess moisture from such types is facilitated. By these physical effects of manure there is a secondary chemical influence on soils because of the greater production of available plant food. The improved physical conditions stimulate bacterial action and this results in more available plant food. Further, the manure adds enormous numbers of bacteria to the soil and hence there is a greater action on unavailable plant food and more is brought into a condition in which it may be utilized by plants. Probably in many cases the addition of manure to soils proves beneficial very largely because of the better bacterial conditions and the greater production of plant food. On heavy types which are high in organic matter this may be particularly true. In general, however, increased crop yields secured from the use of manure are probably due to a combination of the bacterial, chemical and physical effects.

The value of manure as a fertilizer for general farm crops is so large that there should be no question of the importance of carefully preserving this material as produced and applying it in such a way that the largest beneficial influence may be secured. It is still a rather common practice to store the manure in such a way that it suffers much loss by leaching. It has been estimated that when manure is stored in loose heaps exposed to the weather and the leaching action of rains, 70 to 90 percent of the valuable portion of the manure may be lost. When such losses occur the application of manure to the soil will not bring about as large crop increases and hence the improper storage of manure may actually lead to economic losses on the farm. The farmer who is careless in handling the manure may actually be reducing his own income, and is certainly wasting one of the most valuable fertilizing materials available for use.

Manure may be stored in several ways and no one method can be recommended for use under all conditions. It may be composted, it may be stored in a covered yard or it may be kept in a pit or some other satisfactory method may be employed. It is particularly important to note that whatever method is used, the manure should be kept moist and compact and protected from the weather and any method which meets these requirements will cut down the loss of valuable matter. In some cases it may be possible to apply manure as it is produced to the land. When this is possible there is of course no storage problem, but on the average farm direct application is generally not possible or desirable and hence it is usually necessary that some method of storage be adopted. Any

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expense involved will be more than made up by the increased crop yields secured from the use of the manure.

On the average livestock farm the usual application of manure is 8 to 10 tons per acre once in a four-year rotation. Occasionally on light textured soils larger applications than this are made for certain crops but for general farm crops it is usually not desirable to apply more than 16 to 20 tons per acre. On the average livestock farm the production of manure is generally quite insufficient to permit of any large applications to all the soils of the farm. If more than 8 to 10 tons are applied to the soils once in a rotation other soils on the farm are apt to be left without any application. It seems generally more desirable, therefore, that manure be applied at regular intervals and in reasonable amounts to all the soils of the farm in order to permit of the most satisfactory growth of general farm crops.

In order to make up for the lack of farm manure on the average livestock farm and to take the place of that material on the grain farm, the practice of green manuring is commonly followed. Leguminous crops are most desirable for use as green manures because of the fact that when well inoculated they are able to utilize the nitrogen of the atmosphere and fix it in the soil, where it becomes available for the use of subsequent crops. If the supply of organic matter is kept up by green manuring and if legumes are used, the nitrogen content of the soils may also be maintained. Non-legumes may be quite as valuable as legumes from the standpoint of supplying organic matter, but they do not add nitrogen to the soil and hence they are less desirable for general use. Only under unusual soil conditions, where nitrogen is not particularly deficient and the organic matter content is low, would it be desirable to use non-legumes as green manures. There are many legumes available for use under a wide variety of conditions and hence some one may be chosen which will fit in with almost any rotation.

Undoubtedly green manuring may be a profitable practice in some cases in Cedar county where the soils are deficient in organic matter and nitrogen and the supply of farm manure is limited. The practice, however, should not be followed blindly or carelessly, because undesirable effects may result under improper conditions. If moisture conditions in the soil are not entirely satisfactory, there will be very little decomposition of the green material and there may actually be a detrimental effect on succeeding crops, because of the removal of moisture by the green material from the use of the following crop. In order to prove of value, green manures must decompose rapidly in the soil and the practice will not prove of value unless conditions are right for such decomposition. Advice regarding the practice of green manuring under special soil conditions will be given by the Soils Section upon request.

The organic matter content of soils may be kept up in part by the proper utilization of all crop residues, such as straw and stover. Frequently these materials are burned or otherwise destroyed and when this occurs there is a large loss of valuable material and the farmer is actually throwing away an important fertilizing material. On the livestock farm, crop residues may be used for feed and bedding and returned to the soil with the manure. On the grain farm they may be applied directly to the soil or they may be stored under

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proper conditions and allowed to decompose partially before application. On the grain farm the return of all crop residues is of especial importance because of the lack of manure, but it is quite as important that these materials be utilized on the livestock farm in order to aid in keeping up the organic matter content of the soil. Crop residues not only supply organic matter, however, but they return considerable amounts of plant food constituents and hence they actually have an important effect in lengthening the life of the soil. In general crop residues should be considered as valuable supplements to manures and green manures if soil conditions are to be kept most satisfactory for crop growth.

THE USE OF COMMERCIAL FERTILIZERS

The results of the analyses of the soils of Cedar county indicate that their phosphorus supply is inadequate for any large number of crops. In no case is there any large amount of phosphorus present and in most instances the supply is so low that it is evident that phosphorus fertilizers will be needed on these soils in the very near future. Furthermore, it seems quite possible that the use of phosphorus fertilizers might prove profitable at the present time. Where the supply of phosphorus is as low as is the case in some of the soils in this county, it is quite probable that there is an insufficient production of available phosphorus to meet the demands of large crops. Even where the supply of phosphorus is large there is no assurance that there will be sufficient of the element produced is an available form, but when the total amount of phosphorus present is low it is almost certain that the supply of available phosphorus will be inadequate.

The experiments both in the greenhouse and in the field indicate that phosphorus may be a valuable fertilizing material for application to the more extensive soil types in the county. Unfortunately the experiments in this county have not yielded results as yet in confirmation of the observations from greenhouse experiments and from the field tests on the same types in other counties, but it seems quite safe to conclude that phosphorus will undoubtedly be needed on the soils of this county in the near future and that applications of phosphate fertilizers would probably prove of value in many cases now. Farmers are urged to test the need of phosphorus on their own soils by carrying out simple tests in the field. In this way they may secure information of much value for their own farms and they will also aid in the solution of the phosphorus problem for the county as a whole.

Either of two fertilizers may be employed, acid phosphate or rock phosphate. Acid phosphate is more expensive than rock phosphate, but it contains phosphorus in an available form and hence is more readily used by crops. Rock phosphate on the other hand is rather slowly available and much larger applications must be made. A choice between the two phosphorus carriers will depend, therefore, upon the cost of the actual application and the value of the crop increases secured.

The effect of the phosphate materials must be determined over a period of at least four years in order that the rock phosphate may be utilized to the best advantage. This material is applied once in a four-year rotation and is gradually made available, while acid phosphate is added annually. Hence compari-

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sons of these materials should be based on results from at least one four-year rotation.

The experiments referred to in this report do not permit of the making of a choice between these two phosphorus fertilizers and until the experiments now under way in Cedar county have yielded results for several years, it will not be possible to say definitely whether rock phosphate or acid phosphate would prove the most desirable. At present, therefore, it can merely be recommended that farmers test these two phosphorus fertilizers on their farms and determine for their own conditions which material will yield the largest returns. Directions which may be readily followed in conducting tests on the individual farm are given in circular 51 of the Iowa Agricultural Experiment Station.

The soils of Cedar county are not generally very well supplied with nitrogen and in most instances it is quite evident that nitrogen must be taken into account in increasing the fertility of the soils of the county. Only in one case is the amount of nitrogen present very large and in several instances the supply is so low that the soils are in need of nitrogenous materials at the present time. In all cases, of course, nitrogen must be considered in systems of permanent fertility. Even on the soils which are fairly well supplied, the nitrogen will be gradually removed by cropping and in the drainage water. If the supply is to be kept up, some nitrogenous fertilizing material must be employed and where the nitrogen content is low, such materials must be used to build up the supply of this constituent.

The proper utilization of all the manure produced on the farm will permit of the return to the soil of a large part of the nitrogen which has been removed by the crops grown. On the livestock farm, therefore, the nitrogen content of the soil may be much more readily maintained than on the grain farm, but it is not generally possible to keep up the supply of nitrogen by the use of farm manure alone. Even on the livestock farm there is a loss of some nitrogen due to leaching from the soil and to the impossibility of returning all of the crop nitrogen in manure. Hence some other material must be used as a supplement to manure. On the grain farm some nitrogenous fertilizer must be employed in place of manure.

Leguminous green manures are the cheapest and most efficient nitrogenous fertilizers which may be employed. All rotations should contain a legume and with proper inoculation of this legume, a part of the nitrogen which it contains may be drawn from the atmosphere. The actual amount which is taken up from the atmosphere will depend upon certain conditions, such as the vigor of the legume, the extent of inoculation and the nitrogen content of the soil. For average soil conditions it is considered that the nitrogen in the tops of red clover is about equal to that taken from the atmosphere, while the amount in the roots and stubble equals that taken up from the soil. Hence if the crop is removed there will be no loss of nitrogen from the soil, but neither will there be any gain. If the leguminous crop is to be used as a nitrogenous fertilizer, it is generally necessary, therefore, that the entire crop be turned under as a green manure. Occasionally legumes are grown for seed and when the seed only is removed and the remainder of the crop is turned under, there may be a considerable addition of nitrogen to the soil. Occasionally also legumes may

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be used as catch crops in the rotation and in such cases when well inoculated they may add considerable nitrogen as well as organic matter to the soil. The utilization of legumes as green manures would undoubtedly be desirable in some cases in Cedar county in order to build up and keep up the nitrogen supply.

The proper use of all crop residues plays some part in keeping up the nitrogen content of the soil in that such materials contain considerable amounts of nitrogen which have been removed from the soil and when they are properly handled and returned they cut down the losses of this constituent.

Commercial nitrogenous fertilizers cannot be recommended at the present time for general farm crops in this county. They may be utilized in small amounts as top dressings to encourage the early growth of certain crops, but it is hardly likely that they would yield economic returns under the average farm conditions. They may be tested, however, and if they prove of value on small areas, they may be used without fear of injuring the soil. It is probably true that leguminous crops used as green manures will provide a cheaper and more generally satisfactory source of nitrogen.

Analyses of many of the soils of the state reported in earlier publications have shown a large content of potassium and the soils of Cedar county are undoubtedly well supplied with this constituent. There seems to be sufficient present to provide for satisfactory crop yields for many years to come. It is unlikely, therefore, that potassium fertilizers would prove profitable on the soils of the county. Small amounts might be used as top dressings to stimulate the early growth of some crops, but for general farm crops potassium fertilizers cannot be recommended at the present time. Farmers who are interested in such materials may test them on small areas and determine their value under the particular individual conditions. If profitable returns are secured on small areas they may be applied to large areas without fear of injuring the soil.

It is very important that the physical condition of soils be kept satisfactory in order that available potassium may be produced sufficiently rapidly to keep crops supplied. If there is a low production of available potassium, even altho the total content of the soil is high, crops may need this constituent. Hence care should be taken that the soils are well drained and cultivated and well supplied with organic matter. When these factors are properly taken care of there should be a rapid production of available potassium and applications of potassium fertilizers should not be needed. Where these conditions are not satisfactory there may be instances when potassium fertilizers would yield profitable returns.

Complete commercial fertilizers are being tested in the experiments which are now under way in the county and they are being compared with phosphorus fertilizers. Farmers who are interested in any particular brands may test these materials on their own farms. At the present time no definite recommendations regarding the use of these materials can be made. Field data at present available do not show that they are of any more value than phosphorus carriers and inasmuch as they are more expensive than the latter, it would not seem that they would prove as economically desirable. Nitrogen may be more cheaply supplied by the use of legumes and it is unlikely that potassium is necessary on the soils of the county and hence it would be reasonable to con-

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clude that phosphorus fertilizers would yield more profitable returns than the more expensive complete fertilizers. Tests of these materials should include a comparison with rock phosphate and acid phosphate and no conclusions regarding their value should be drawn unless comparative yields have been secured, owing to the fact that it is believed from preliminary indications that the phosphorus carriers will yield quite as profitable or even more profitable returns.

There is no objection to the use of complete commercial fertilizers if they prove of profit. They do not injure the soil and they may not be too expensive if the value of the crop increase secured proves larger than the cost of the materials, but they should not be applied to large areas until tests have been carried out on a small scale and they have been compared with phosphorus fertilizers. Particular emphasis should be placed upon the economic value of the materials in comparison with phosphorus carriers.

DRAINAGE

The natural drainage system of Cedar county is apparently quite adequate and in general it may be said that the soils of the county are fairly satisfactorily drained. There are some cases, however, where drainage would improve the fertility of the soil and bring about more satisfactory conditions for the growth of crops. There are some areas in the Muscatine silt loam, the most extensive soil type in the county, where the topography is rather flat, in which the drainage is not quite adequate. The Clyde silty clay loam and the Scott silt loam are quite generally in need of drainage. Both of these types occur in depressed areas in the upland and this topographic position, together with the heavy texture of the subsoil, leads to the slow removal of moisture and hence to unsatisfactory conditions, particularly in wet seasons, for the best growth of crops. The bottomland soils are in general poorly drained and the Calhoun silt loam, a terrace type, is likewise in need of drainage. In all these cases the proper tiling of the soils will lead to increased crop production and unless the areas are properly tiled out, crops will not be satisfactory and in wet seasons may be totally ruined.

No other treatment of any soil will prove of value if the type is poorly drained and hence fertilization of any kind should not be practiced until drainage is made adequate. The expense of the installation of tile is not great and the returns which are secured from its use are large and will more than offset the expense involved. There need be no difficulty in the securing of proper outlets for tile laid in the soils mentioned, where drainage is necessary, and hence the tiling operation may be accomplished without great difficulty. It should be urged, therefore, that whenever the soil conditions in Cedar county give evidence of lack of drainage, tile be installed and only by the proper use of tile may crop yields on soils which are too wet be made entirely satisfactory.

THE ROTATION OF CROPS

The continuous growing of any one crop on a soil leads very rapidly to a depletion in the fertility of that soil. Frequently the value of a particular crop will lead farmers to grow that crop continually, even tho they are aware that

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they are depleting their soils in fertility very rapidly. The fact that such continuous cropping to one crop, even tho the crop happens to be a money crop, does not provide the largest income from the land over a period of years, is largely lost sight of. Experiments have been carried out at various times and in many places which have demonstrated very clearly that the income from the crops grown on land is very much greater where a rotation is practiced, even in spite of the fact that there are included in the rotation crops which command less market value. This is due to the fact that the yields of the money crop in the rotation are kept up and even increased when the proper crop rotation is followed and hence the total value of all crops in the rotation will exceed that of the same number of crops where continuous cropping is practiced.

It is impossible to recommend any particular rotation of crops as suitable for all conditions but several rotations are in use thruout the state and from among these some one may be chosen which will fit almost any condition. Modifications of these rotations may be practiced if desired and in fact it may be said that almost any rotation of crops will prove desirable, provided a legume crop is included and the money crop. The following are rotations which are in common use in the state and any of them may be followed in Cedar county:

1. FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation).
Second Year—Corn.
Third Year —Oats (with clover or with clover and timothy).
Fourth Year —Clover. (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

2. FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.
Second Year—Oats.
Third Year —Clover.
Fourth Year —Wheat.
Fifth Year —Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

3. THREE-YEAR ROTATION

First Year —Corn.
Second Year—Oats or wheat (with clover seeded in the grain).
Third Year —Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw, should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm

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will wash the soil badly. When the soil is thoroly wet, the rain falling on it will, of course, wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion, while heavy soils, such as loams, silt loams and clays, may suffer from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion, while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance, but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Cedar county erosion occurs to a considerable extent in the Clinton silt loam and the Lindley silt loam and there are some areas in the Tama silt loam and the Carrington silt loam where there is considerable washing away of the surface soil. Gullies are sometimes formed in these soils and in the case of the Clinton and Lindley soils they may develop to a considerable extent, especially in the rougher portions of these soil types. In other cases in the uplands the erosion may consist mainly of a washing away of the surface soil or sheet erosion, in which case the destructive action will not be so apparent but will be quite as injurious.

It is very important that some means be taken to protect all these soils from the injurious effect of erosion and from among the methods suggested here, one may be chosen which will serve under almost any condition. There are probably

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some cases where the soil should preferably be left in pasture if extensive washing is not to occur. The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In." It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In." The method of "staking in" is better, as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams. Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls. The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

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"Staking In." The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward is left near the top. This heavy branch is caught between a fork in the lower part of the brushpile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as rapidly by the action of a large volume of water. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of staking in which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the staking in method is proving very satisfactory.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material, and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam. The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam. This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called

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the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam. This dam is practically the same as the Christopher or Dickey dam. In fact, the principle of construction is identical. In some sections the name "Adams dam" had been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an upstream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam. Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam. The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish, even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam. The use of woven wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips. The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small, as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or

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alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The Concrete Dam. One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage. The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such low-lying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling. The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees. Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features, it is not generally desirable. The row of trees often extends much farther into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

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HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter. Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues, such as straw and corn stalks, may also be turned under in soils to increase their organic matter content. In general, it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops. The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also quite desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing. Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Fig. 5. Clinton silt loam along the Cedar river in Cedar county is often subject to erosion.

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Sod Strips. The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing. Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation, as too much subsoil may be mixed with the surface soil and the productive power of the soil, therefore, reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and, therefore, less subject to erosion.

INDIVIDUAL TYPES IN CEDAR COUNTY *

There are fourteen individual soil types in Cedar county and these, together with the colluvial phase of the Wabash silt loam and an area of meadow, make sixteen separate soil areas. These are divided into four large groups according to their origin and location. These groups are known as drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are three drift soils in the county, belonging in the Carrington, Lindley and Clyde series, and together they cover 11.3 percent of the total area of the county.

CARRINGTON SILT LOAM (83)

The Carrington silt loam is the most extensive drift soil in the county and the fourth largest type. It covers 10.8 percent of the total area of the county. It occurs entirely in the northern part of the county, the largest development being found in the northeast corner covering a large part of Massillon township, the eastern portion of Dayton township and a small part of Springfield township. Other areas are found in the northwestern part of the county, one occurring in the northwest corner extending in a narrow strip as far as Mechanicsville and a second extending from the western boundary of the county at the Johnson county, Linn county boundary line in a narrow strip southeastward to Buchanan. There are small areas along the northern boundary of the county north and east of Mechanicsville and small areas north and east of Buchanan.

The surface soil of this type is a dark brown mellow silt loam 15 to 18 inches in depth. The subsoil is a yellowish-brown friable silty clay loam passing at 28 to 30 inches into a fine sandy clay. Mottlings of gray and brown occur in the lower part of the three-foot section. In some of the flatter areas the surface soil is somewhat darker in color and may consist of a black silt loam. In these areas the surface soil is also somewhat deeper than typical. Small areas of Carrington loam are found along the county line north of Massillon adjoining

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report.

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Fig. 6. Carrington silt loam is gently rolling in topography.

the same type in Clinton county. These areas are so small that they have not been shown separately on the map. Small areas of sand and loam are frequently found, particularly on the tops of the hills, but there are too small to map separately. In general the gravel of the till is found just within the three-foot section. Boulders occasionally occur but not in large numbers in any case. The boundary line between the Carrington silt loam and the Muscatine silt loam is very difficult to draw in many cases and the separation has been based upon the occurrence of the glacial material within the three-foot section.

In topography the Carrington silt loam ranges from almost level to undulating. Drainage is generally sufficient but in some of the flatter areas the soil may be too wet and tiling will prove of value.

Practically all of the Carrington silt loam is cultivated, the chief crops grown being corn, oats and hay. Corn is by far the most important crop and occupies the largest acreage. Much of the corn produced is used for ensilage and the remainder is used as feed on the farms. The varieties of corn most generally used are Reid's Yellow Dent, Silver King, Goldmine, Silvermine and Johnson County White. Corn yields range from 35 to 65 bushels per acre and the early maturing varieties give the best results. Yields of oats average from 30 to 60 bushels per acre and the varieties most generally grown are Iowa 105 and 103. The yields of hay amount to one to three tons per acre on the average and as in the case of the corn and oats, the entire production is used for feed on farms. Some wheat, rye and barley are grown, the latter crops being fed on the farms, while the wheat is largely shipped out of the state. The raising of livestock is practiced generally on this soil and the industry consists chiefly of feeding beef cattle, dairying and hog raising.

Crop yields on the Carrington silt loam are in general quite satisfactory but they may be increased thru proper soil treatments. The application of manure

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is particularly valuable on this soil and large increases in crops may be secured thru the proper use of this material. The soil is acid and in need of lime and if the best growth of legumes is to be secured it must be tested and lime applied as needed. The type is low in phosphorus and phosphorus fertilizers will probably prove of value at the present time. They will undoubtedly be needed in all cases in the future. The experiments which have been reported in this bulletin and much farm experience show the large value from the use of manure and lime and indicate that profitable returns may result from the use of phosphorus. Tests of phosphorus fertilizers on this soil on individual farms are urged. In all cases where drainage is inadequate tile should be installed and wherever erosion is occurring proper methods should be practiced to prevent the occurrence of this injurious action.

LINDLEY SILT LOAM (32)

The Lindley silt loam is a minor type in the county, covering only 0.3 percent of the total area. It occurs entirely in the northwestern part of the county and is found along the steeper slopes bordering the streams, separating the Clinton, Carrington and Tama soils of the uplands from the Wabash of the bottoms. The largest areas of the type occur along Clear creek and Baldwin creek in Pioneer and Linn townships.

The surface soil of the Lindley silt loam is a gray to grayish-brown friable silt loam 7 to 10 inches in depth. The subsoil is a yellowish-brown fine sandy clay generally passing into a gritty sandy clay at 30 to 34 inches. Mottlings of gray usually occur in the lower subsoil. On the more gentle slopes the surface soil generally has a brown to dark brown color and is deeper. On the steeper slopes rock outcrops frequently occur. In some areas where erosion has been active bedrock appears within the three-foot section.

In topography the Lindley silt loam is rolling to strongly rolling and drainage is generally excessive. The type is subject to erosion and in many areas the surface soil has been very largely washed away. A part of the type supports a forest growth of oak and hickory. Very little of it is cultivated and it is used mainly as pasture. The cultivated portion on the more gentle slopes is used for corn, oats and hay and the yields of these crops are smaller than those secured on the surrounding upland types.

The cultivated portions of the Lindley silt loam may be made more productive thru proper methods of treatment. Applications of farm manure are very desirable and large amounts of this material may be used to advantage. The type is acid and in need of lime. Phosphorus fertilizers will undoubtedly prove of value. Protection from erosion is particularly important and if the soil is to be cultivated satisfactorily the washing away of the surface soil must be prevented. The steeper slopes of the type should undoubtedly be left in pasture or forest.

CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is a very minor type in the county, covering only 0.2 percent of the total area. It occurs only in the northern part of the county in five areas just north and west of Stanwood. It occupies flat to depressed areas near the heads of streams, and the two larger areas are just north of Stanwood.

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The surface soil of the Clyde silty clay loam is a black silty clay loam 9 to 15 inches in depth. The subsoil is a mottled gray, brown and yellow silty clay loam to silty clay. Iron stains frequently occur in the lower subsoil. Where the drainage of the type is particularly poor the subsoil is very gray and is plastic and sticky in texture.

Very little of the Clyde silty clay loam is cultivated, most of it being in pastureland. When artificially drained excellent yields of corn and hay are secured. Small grains are not grown as satisfactorily, owing to their tendency to lodge. Corn yields 60 to 90 bushels per acre, oats 35 to 40 and hay 1½ to 2 tons. The chief need of the Clyde silty clay loam to make it satisfactorily productive for cultivated crops is the installation of tile. When adequate drainage is accomplished excellent crop yields may be secured. Small applications of farm manure would undoubtedly be of value on newly drained areas. The soil is acid and in need of lime and the use of this material together with drainage will improve the physical condition of the type. Phosphorus fertilizers will undoubtedly be necessary in the future and may prove of value in some cases at the present time.

LOESS SOILS

There are five loess soils in the county, classified in the Muscatine, Tama, Clinton, Knox and Scott series. Together they cover 81.5 percent of the total area of the county.

MUSCATINE SILT LOAM (30)

The Muscatine silt loam is the most extensive soil type in the county, covering 29.8 percent of the total area. This type is developed in all parts of the county, the largest areas occurring in the eastern part in the vicinity of Sunbury,

Fig. 7. The roads thru the level Muscatine silt loam areas are well-kept and frequently dragged.

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Durant, Bennett, Clarence and Stanwood. In fact, there seems to be an almost continuous area of this type extending diagonally across the county from the county line north of Stanwood and Clarence to the southeastern corner of the county at Durant, this area of Muscatine being cut up by various streams and intermittent drainageways, which are bordered by areas of Tama on the upland. Considerable areas of the Muscatine silt loam occur in all other parts of the county in association with the Tama, Clinton and Carrington soils of the upland and in general occurring on the gently undulating to level areas. It normally occupies the broader and more level upland areas between the streams, occasionally, however, extending down gentler slopes to the streams.

The surface soil of the Muscatine silt loam is a brown to dark brown mellow silt loam 17 to 20 inches in depth. The subsoil is a light brown to yellowish-brown heavy silt loam to silty clay loam passing at 24 to 30 inches into a light brown to yellowish-brown compact silty clay loam to silty clay mottled with brown, gray and yellow. Some variations of the type occur in various parts of the county. There is an area 1½ miles south of Bennett where the surface soil is dark brown to almost black in color and grades at 10 to 12 inches into a light brown silty clay. The subsoil below 16 to 18 inches is a yellowish-brown silty clay passing at 24 inches into a lighter brown silty clay mottled with gray and yellow and streaked with iron stains. In the flatter areas around Bennett the gray mottlings are very pronounced in the subsoil and frequently it is predominantly gray in color. There are areas similar in these characteristics just east of Durant and east of the Cedar river along the county line. Three miles due south of Bennett there is a subsurface layer of mottled gray and brown 8 to 12 inches in thickness separating the surface soil from the typical subsoil.

There are included within the Muscatine silt loam small depressed areas somewhat heavier in type which could not be separated owing to their small extent. The boundary line between this soil and the Carrington silt loam in the northeastern part of the county is difficult to locate and the occurrence of glacial material in the subsoil has been the determining factor in separating these types.

In topography the Muscatine silt loam is level to gently rolling. In most cases the drainage is adequate but in the flatter areas tiling is necessary for the best growth of crops.

Practically all of this type is in cultivation or devoted to pasture. Corn, oats, hay, barley and wheat are the most important crops. Corn occupies the largest acreage and yields 40 to 90 bushels per acre with an average of about 42 bushels Practically all of the corn produced is fed on the farms, only a small amount being shipped out of the county. Oats yield 28 to 60 bushels per acre, barley 18 to 35 bushels per acre and hay one to two tons per acre. These crops are all used as feed on the farm. Wheat is grown on a small acreage and yields 15 to 25 bushels per acre. The entire crop is sold and shipped out of the county. Potatoes are grown largely for home use and yields of 125 bushels per acre are secured. Apples, strawberries and raspberries are grown to some extent for home use and the raising of apples, particularly, might prove very profitable with proper care of the orchards. Alfalfa is grown in a few instances

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and when the soil is properly limed and inoculation is practiced, yields of this crop have amounted to 2 to 4 tons per acre.

The Muscatine silt loam is normally a very productive soil and crop yields are quite satisfactory. In some areas, however, the type is poorly drained. When this is true tiling is very desirable. Crop yields may be increased to a considerable extent thru the removal of excess moisture. Applications of farm manure prove of value on this soil in spite of the fact that it is high in organic matter. The beneficial effect of this material on crop yields may be due to the greater production of available plant food. The soil is acid and in need of lime, particularly for the best growth of legumes. Yields of these crops are very largely increased thru the proper application of lime. Phosphorus fertilizers may prove of value in many cases at the present time and will certainly be needed in the future. Experiments on this soil indicate the large effects on crops from the application of farm manure and lime and farm experience very largely confirms these indications. The experiments indicate also the value of phosphorus fertilizers and it remains for a test on individual farms to determine whether or not these materials may be used with profit at the present time.

TAMA SILT LOAM (120)

The Tama silt loam is the second largest soil type in the county, covering 26.3 percent of the total area. It is developed in all parts of the county, the largest areas occurring in the northern part of the county around Stanwood and in the southwestern part of the county in the vicinity of West Branch. Other considerable areas occur in the vicinity of Tipton, southeast of Mechanicsville and along the Little Elkhorn creek in the southeastern part of the county. It occurs in many narrow areas along the stream courses and in isolated areas frequently separating the more level Muscatine silt loam of the upland from the bottoms.

The surface soil of the Tama silt loam is a brown to dark brown mellow silt loam 10 to 15 inches in depth. The subsoil is a light brown to yellowish-brown heavy silt loam grading at 24 inches into a yellowish-brown friable silty clay loam. Gray mottlings sometimes occur in the lower subsoil. Some variations from the typical soil occur and in the area two miles south of Sunbury the surface soil is not so deep as typical ranging from 6 to 9 inches. Along some of the lower slopes the surface soil is a light brown silt loam 6 inches in depth underlaid by a grayish-brown floury silt loam, which grades at 18 to 24 inches into a grayish-brown silty clay loam to silty clay mottled with brown and yellow. These areas are too small to map separately. In areas adjoining the Clinton silt loam, the surface soil is frequently a light brown to grayish-brown and the boundary line between these types is frequently very difficult to draw. The boundary between this type and the Muscatine silt loam is also difficult to locate, as there is a gradation between the two types which cannot be mapped separately. In topography this type is strongly undulating to rolling and the drainage is quite adequate.

Practically all of the type is under cultivation or in pasture. The only forested areas are small windbreaks mostly of evergreens and maple and small tracts of catalpa grown for fence posts. Corn, oats, hay and wheat are the

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principal crops grown and the yields are slightly lower than those secured on the Muscatine silt loam. All of the wheat produced is shipped out of the county and some of the corn is disposed of in this way. Most of it, however, is used for feed and some barley and rye are grown and used for feeding purposes. Clover, sweet clover and sometimes alfalfa are grown in the rotation and occasionally soybeans are planted with the corn. Bluegrass is used generally for pasture and grows luxuriantly on this soil. The hay crop consists chiefly of clover and timothy and the second year usually consists of timothy alone. Alfalfa yields three to four tons per acre when the soil is properly prepared and limed and the seed inoculated.

The Tama silt loam is a rather productive soil but crop yields may be increased thru the proper application of fertilizing materials. Farm manure is an extremely valuable fertilizer for use on this soil and this material should be applied in considerable amounts. The soil is acid and in need of lime. For the best growth of all legumes this material must be applied. The phosphorus content is not high and phosphorus fertilizers may prove of value at the present time. They will certainly be needed in the future. The experiments on this type show the large returns which may be secured from the proper use of farm manure and lime and they indicate also the possible value from the application of phosphorus carriers. Tests on the individual farm are needed to show definitely the effect of phosphorus on crop yields and to show also which phosphorus carrier may be used most profitably.

CLINTON SILT LOAM (80)

The Clinton silt loam is the third largest type in the county, covering 24.2 percent of the total area. It is developed along both sides of the Cedar river along its entire course, the areas varying in width from one to five miles. It occurs in extensive areas also along some of the larger creeks and on the west

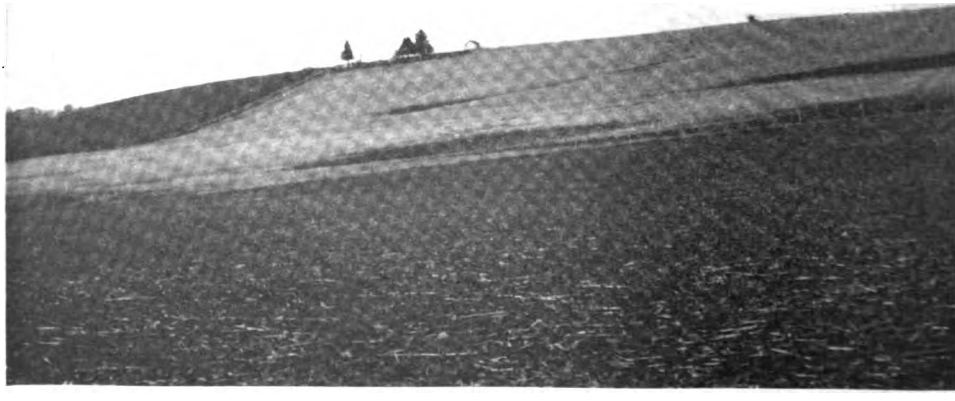

Fig. 8. Clinton silt loam topography, showing dark seepage spots.

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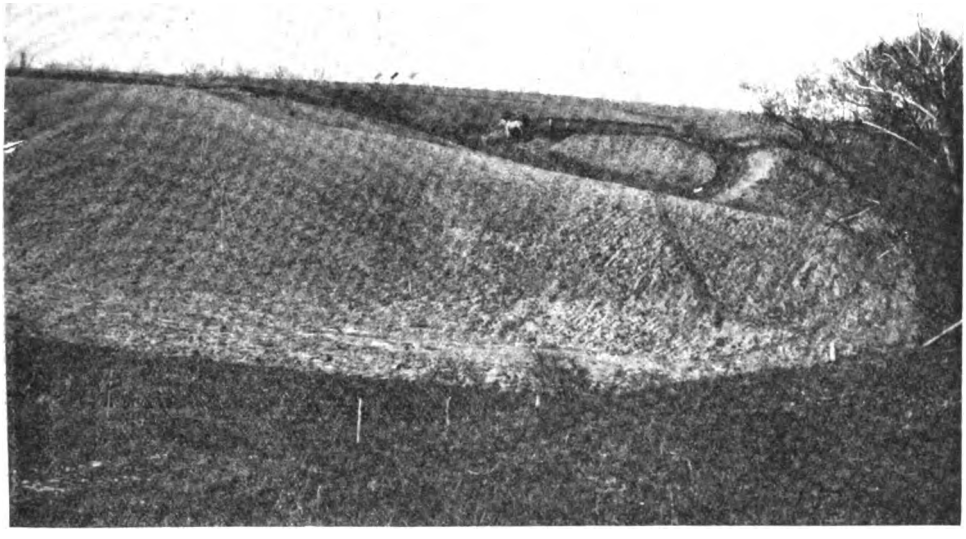

Fig. 9. Plowing sod on Clinton silt loam for corn.

side of the Wapsipinicon river. In addition to these areas along the streams there are some smaller isolated bodies at the heads of some of the intermittent drainageways. The largest area of the type is found south and west of Tipton covering a large part of Center, Rochester and Gower townships. Considerable areas in Iowa and Sugar Creek townships are also included in this type and there is a large area in the eastern part of the county in Springfield township.

The surface soil of the Clinton silt loam is a light grayish-brown to light brown floury silt loam 7 to 12 inches deep. The subsoil is a yellowish-brown to light yellow friable silty clay loam to silty clay faintly mottled with gray in the subsoil. On the steeper slopes the surface soil is thinner than the typical and on the broader and more level areas and especially just south of Rochester it is somewhat deeper, ranging from 10 to 15 inches in thickness. In the timbered areas the upper two-inch layer of the soil is dark brownish-gray to brown in color.

In topography the Clinton silt loam is strongly rolling to rough and broken. Along the Cedar river it occurs on steep slopes, some of which are eroded. Along the smaller creeks and in the isolated areas of the type the topography is more gently rolling and not so rough. Just south of Rochester the soil occurs on a rather level upland. Drainage is entirely adequate in the type and may sometimes be excessive.

The larger part of the Clinton silt loam is devoted to pasture and much of it is forested with oak, walnut, hickory and some elm, ash and basswood. The more smoothly rolling areas are cultivated and corn, oats, wheat and hay are the principal crops grown. Corn yields 35 to 60 bushels per acre, oats 18 to 50, wheat 15 to 20 bushels and hay 1 to 2 tons. Some barley is grown, yielding 15 to 36 bushels per acre. Bluegrass grows well and makes excellent pasturage.

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Fig. 10. The destructive action of erosion in the Clinton silt loam must be controlled for successful crop production.

The Clinton silt loam is not as productive a type in the cultivated portion as the Muscatine and Tama soils. It is low in organic matter and applications of farm manure are particularly needed. Large crop increases are secured from the liberal application of farm manure. The soil is acid and in need of lime. This material must be used if clover, alfalfa and other legumes are to be grown successfully. Such crops are of particular value on this soil and should be handled in such a way that large amounts of organic matter will be added to the soil. Phosphorus will be needed on this soil in the future and phosphorus fertilizers would probably prove of value now. In some of the steeper areas the type should probably be left in pasture, and in the cultivated areas it is very important that care be taken to prevent the destructive action of erosion.

KNOX FINE SAND (33)

The Knox fine sand is a minor type in the county, covering 1.1 percent of the total area. It occurs mainly along the Cedar river, the largest areas being developed near Cedar Bluff, around Rochester, and southeast of Rochester in the bend of the river. Other small areas are found along the Wapsipinicon river, and in other localities near the Cedar river.

The surface soil of the Knox fine sand is a brown to dark brown fine sand to loamy fine sand, 12 to 16 inches in depth, underlaid to a depth of three feet by yellowish-brown to yellow incoherent fine sand. Between the small knolls which are characteristic of the type there are depressed areas where the surface soil is a brown to almost black light fine sandy loam passing at 10 to 12 inches into a yellow fine sand. On the tops of knolls and hills the soil is generally a pale yellow to gray fine sand and there is no difference in color or texture to a depth of three feet.

In topography the Knox fine sand is undulating to rolling. Near Cedar Bluff it consists of small knolls and intervening shallow depressions. Drainage is excessive and crops ordinarily suffer from drouth.

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Only a small part of the Knox fine sand is cultivated, a greater portion being in pasture. The cultivated portion is farmed along with the adjoining Clinton and Muscatine soils and the same crops are grown. Crop yields, however, are lower than on the Clinton silt loam. In some areas watermelons, cantaloupes and garden truck are grown and excellent yields are secured.

This type is particularly in need of organic matter if it is to be made satisfactorily productive. Liberal applications of farm manure are needed and it would also be desirable to turn under leguminous crops as green manures quite frequently. The soil is acid and in need of lime. It is low in phosphorus and phosphorus fertilizers should undoubtedly be employed. Where truck crops are grown the application of complete brands of fertilizers, particularly designed for such crops, may often be used to advantage. It is probably most desirable that melons, sweet potatoes and garden truck be grown on this soil, as the soil is particularly suited for such crops.

SCOTT SILT LOAM (154)

This is a minor type in the county, covering only 0.1 percent of the total area. It occurs in small isolated areas in Inland township in the southeastern part of the county, occupying depressions in the flatter areas of the Muscatine silt loam and in Rochester township, where it occurs in depressions in the Knox fine sand.

The surface soil of the Scott silt loam is a black silt loam, extending to a depth of 10 to 15 inches, at that point changing to a gray floury silt loam faintly mottled with yellow. At 18 to 20 inches the subsoil is encountered and this consists of a gray tenacious silty clay mottled with brown, gray and dark orange. Iron concretions occur in the lower part of the soil section. In some areas the surface of the soil to a depth of two to three inches is peaty in nature. This type is developed in depressions in the upland and represents old filled in lake beds or ponds. Drainage is lacking in many cases and is usually poor.

The type is unimportant agriculturally and is usually left in natural grasses and weeds. If properly drained and handled profitable general farm crops might be raised. The type is never sold separately but always in connection with the surrounding upland and in addition to tiling would be benefited by applications of manure, lime and phosphorus fertilizers.

TERRACE SOILS

There are four terrace types in the county, classified in the Buckner and Calhoun series. Together they cover a total of 1.2 percent of the county.

BUCKNER SILT LOAM (36)

The Buckner silt loam is the largest of the terrace soils, covering 0.5 percent of the total area of the county. It occurs on the terraces along the Cedar and Wapsipinicon rivers, the largest areas occurring in the vicinity of Cedar Bluff and south of Rochester.

The surface soil of the Buckner silt loam is a dark brown mellow silt loam 17 to 20 inches in depth, underlaid by a lighter brown to faintly yellowish-brown heavy silt loam to silty clay loam. Near Downey the surface soil is brown to

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almost black and the subsoil at 30 to 33 inches grades into a yellowish-brown silty clay loam mottled with brown and gray. Small areas near Massillon differ from the typical soil but have been included owing to their small extent. In these areas the surface soil is a dark brown to black silt loam passing at 8 to 12 inches into a yellowish silty clay which extends to 24 or 30 inches. The lower subsoil is a yellowish-brown silty clay mottled with brown and yellow, often grading at three feet into an impervious bluish-gray to dark drab clay. On the Johnson county line on both sides of the Cedar river the soil resembles the Waukesha silt loam but the areas are too small to separate out and were included with the Buckner.

In topography the Buckner silt loam is nearly level and the type lies about 10 feet above the first bottoms and 15 feet above the level of the stream. Drainage is entirely adequate.

Practically all of the type is under cultivation. General farm crops are grown, the largest acreage being in corn. Average yields of this crop amount to 80 bushels per acre. Oats yield 30 to 60 bushels per acre and hay 1½ to 2 tons. Some wheat and rye are grown. Practically all of the farm crops produced, with the exception of wheat, are used as feed on the farms and there is very little sold out of the county.

The Buckner silt loam is normally a rather productive soil but will respond, however, to applications of farm manure. It is acid and in need of lime and phosphorus fertilizers would undoubtedly prove of value in many cases.

BUCKNER FINE SAND (46)

The Buckner fine sand is of minor occurrence in the county, covering 0.4 percent of the total area. It occurs on the terraces along the Cedar river, chiefly in the vicinity of Cedar Bluff, near Rochester and east to the river near the Muscatine county line.

The surface soil of the Buckner fine sand consists of a brown to light brown fine sand to slightly loamy fine sand, 8 to 10 inches in depth, underlaid by a brown to yellowish-brown fine sand which extends to a depth of three feet or more. In some areas the surface soil is a pale yellowish-brown to grayish-brown fine sand, passing at 10 to 12 inches into a pale yellow fine sand. The areas near Rochester are of this description. Within the type there are included small areas of the fine sandy loam which cannot be shown separately on the map.

In topography the Buckner fine sand is level and drainage is excessive. In ordinary seasons crops will suffer from drouth, and the type is usually allowed to remain in native grasses and is utilized for pasture. Very little of it is cultivated, some corn being grown and in some areas watermelons, cantaloupes and potatoes are produced. Yields are somewhat lower on this soil than on the Buckner silt loam with which it is associated. This type is low in plant food and organic matter and should receive liberal applications of farm manure and leguminous crops should be turned under as green manures. It is acid in reaction and in need of lime. It is low in phosphorus and phosphorus fertilizers will undoubtedly prove of value.

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Fig. 11. A building stone quarry in the Cedar river valley.

BUCKNER FINE SANDY LOAM (45)

The Buckner fine sandy loam is a minor type in the county, covering 0.2 percent of the total area. It occurs in small areas along the Cedar river, chiefly in the vicinity of Cedar Bluff.

The surface soil of this type is a brown light textured fine sandy loam 8 to 10 inches in depth. The subsoil is a light brown to yellowish-brown heavy fine sandy loam to fine sandy clay loam. There are included within the type a few areas of Buckner silt loam which are too small to separate on the map.

In topography this soil is level to gently sloping and the drainage is good. It lies above ordinary overflow, having an elevation of from 12 tc 20 feet above the normal level of the river.

Practically all of the type is cultivated and corn, oats and hay are the chief crops grown. Watermelons, cantaloupes, potatoes and all kinds of garden truck are produced on a small scale for home use. This soil is particularly well suited for such crops and would yield more profitably for such crops than for general farm crops.

This type is particularly in need of organic matter, should receive liberal applications of farm manure and leguminous crops should be turned under as green manures. The soil is acid and in need of lime. Phosphorus fertilizers would undoubtedly prove of value. Where truck crops are grown the addition of commercial fertilizers would probably be profitable.

CALHOUN SILT LOAM (42)

This is a minor type in the county, covering only 0.1 percent of the total area. It occurs in two small areas in the county, one three miles directly south of Rochester and the other southeast of Downey.

The surface soil of the type is a light brown to grayish-brown silt loam 14 to 16 inches in depth. The subsoil is a gray floury silt loam passing at 20 to 24 inches into a gray silty clay mottled with gray, brown and yellow. Iron

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concretions frequently occur in the lower subsoil. When dried the surface soil is grayish and floury. In the area southeast of Downey the soil is a brown to dark brown mellow silt loam 15 to 16 inches in depth, passing into a gray layer having a silty clay loam texture.

In topography this soil is level to gently sloping and drainage is fairly adequate. It occurs on terraces lying two to six feet above the first bottoms and 8 to 10 feet above the normal level of the streams.

About half of the type is cultivated and used for the production of general farm crops. Yields are somewhat lower than those secured on the Buckner silt loam. The area in pasture supports a good growth of grass and the tree growth on these areas consists mainly of a few oaks, elm and maple. This soil will respond to applications of farm manure. It is acid and in need of lime and applications of phosphorous fertilizers would undoubtedly prove of value. In some instances tiling would improve the drainage condition.

SWAMP AND BOTTOMLAND SOILS

There are four areas of swamp and bottomland soils in the county, three of them belonging in the Wabash series, and the fourth area is described as meadow. The total area covered by these soils amounts to 6.0 percent of the county.

WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland type and it is the fifth largest type in the county and, together with the colluvial phase, which is minor in extent, covers 9.4 percent of the county. It is developed along the first bottoms of the various rivers and creeks in the county and it is found in all parts of the county in narrow inextensive areas. The largest area of the type occurs along Yankee Run south and west of Lowden. Here the bottomland

Fig. 12. Narrow strips of Wabash loam occur along all the streams. Adjacent uplands are Tama silt loam.

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extends for a width of a mile. In other areas the type occurs in belts of a few yards to a quarter of a mile in width.

The surface soil of the Wabash silt loam is a dark brown to black silt loam, 15 to 20 inches in depth. The subsoil is a dark drab to dark gray or grayish-brown silty clay loam to silty clay, mottled in the lower depths with rusty brown and yellow. In some areas the surface soil to a depth of two to three inches is lighter in color, ranging from a brownish-gray to a light brown.

In topography this soil is level to flat, in some cases sloping very gently toward the streams. It occurs from two to six feet above the normal level of the streams and is subject to overflow. Drainage is adequate during normal seasons but in wet seasons it is poor.

Very little of the type is cultivated, a greater portion being used for pasture. A very small area is in forest, which consists principally of willow. Corn is the principal cultivated crop grown, yields ranging from 35 to 80 bushels per acre. The type affords excellent pasturage and probably it would be more desirable in general to utilize it for pasture than for cultivated crops. Protection from overflow is very necessary if cultivated crops are to be grown. When this is accomplished small applications of farm manure would be of value, lime should be used to neutralize the acid condition and phosphorus fertilizers might be employed to advantage.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

This is a minor type in the county, covering less than one percent of the total area. It occurs along some of the smaller streams of the county and is produced by the washing down of the soil from the upland upon the bottomland along the streams. The type occurs in association with the Tama silt loam, Muscatine silt loam and the Carrington silt loam.

The surface soil of the colluvial phase of the Wabash is a dark brown to black silt loam, 10 to 12 inches in depth, underlaid by a black silty clay loam to silty clay which extends to a depth of three feet. This phase lies one to four feet above the stream levels and as a rule is poorly drained. In some areas water stands the greater part of the year. Most of the soil is left in pasture and supports a luxuriant growth of grass. When cultivated, corn is the principal crop grown. Oats are grown but have a tendency to lodge.

This soil is particularly in need of drainage and when cultivated would respond to applications of farm manure, lime and phosphorus fertilizers.

MEADOW (20)

There is a small area of meadow in the county, covering 0.8 percent of the total area. It occurs along the Cedar river and the Wapsipinicon river, the largest area being found on the Johnson county line and just northwest of Cedar Bluff in a narrow area extending from Rochester to the Muscatine county line and along the Wapsipinicon river in the northeast corner of the county. Within these areas mapped as meadow, there are included a mixture of riverwash, Cass and Wabash soils so mixed up that the soil types represented cannot be separated. It represents material recently deposited by the streams, is composed principally of dark brown to black surface soils with subsoils ranging from sands to clays. It has little or no agricultural value and the areas in

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general are largely supporting a luxuriant growth of grass and weeds. Clumps of willows are occasionally found along the stream banks.

WABASH SILTY CLAY LOAM (48)

This is a minor type in the county, covering 0.3 percent of the total area. It occurs in the first bottoms along the Wapsipinicon river, the middle and east branches of Wapsinonoc creek and along Rock and Pioneer creeks. The largest areas occur along Pioneer creek and along the middle branch of the Wapsinonoc.

The surface soil of the Wabash silty clay loam is a very dark brown to black silty clay loam 12 to 17 inches in depth. The subsoil is a dark drab to dark gray plastic silty clay faintly mottled with brown. Iron stains are commonly found in the lower depths. This type varies somewhat in texture and color. Often the surface four or five inches is a black silt loam. Occasionally the dark drab subsoil will grade into a gray silty clay at 30 inches. In many cases the amount and character of the mottlings will vary widely.

In topography this soil is flat. It lies two to four feet above the normal water level. It is subject to overflow and is poorly drained. The areas along the Wapsipinicon river are swampy.

About 10 percent of the area of this soil is in cultivation. With the exception of a few forested areas in which the principal trees are oak and willow, there is a good growth of grasses and weeds which make good pasturage. Corn is the principal cultivated crop and yields are comparable with those secured on the Muscatine silt loam.

This soil should be protected from overflow and adequately drained before it can be made productive for general farm crops. Small applications of farm manure would then be of value, lime should be used and phosphorus fertilizers would undoubtedly be of value. Much of the type should probably be left in pasture, as grasses make an excellent growth and unless the soil is protected from overflow it would be unwise to attempt the growth of general farm crops.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil tyes, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

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AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their

*Bulletin 150, Iowa Agricultural Experiment Station.

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food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the

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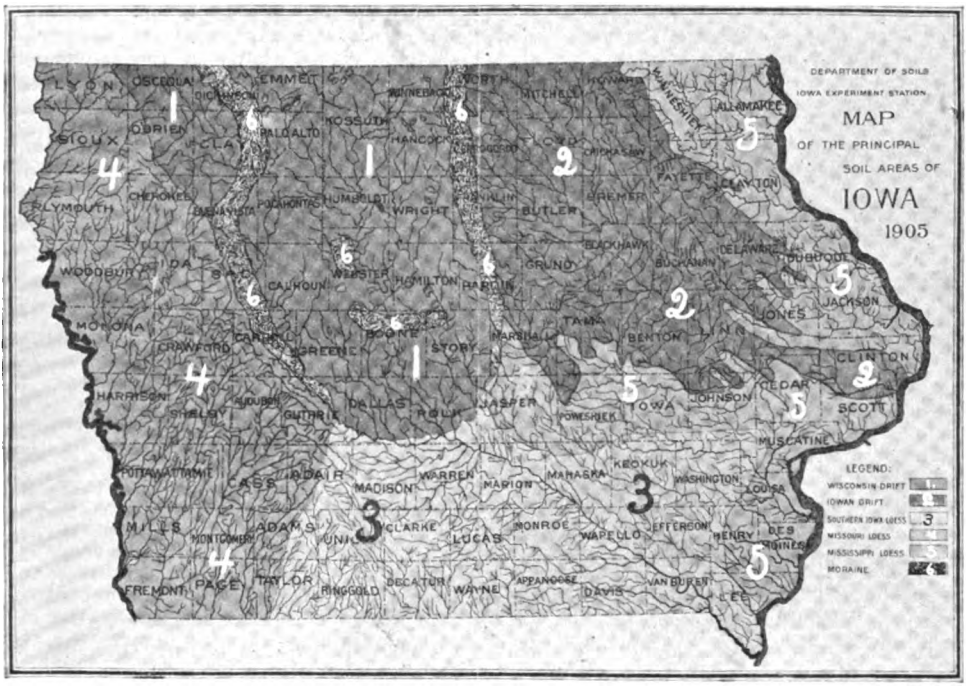

Fig. 13. Map showing the principal soil areas in Iowa

tests of many representative soils reported in bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 13.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by

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differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made, The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2.0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0.05 mm. Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.‡

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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June, 1923 Soil Survey Report No. 29

SOIL SURVEY OF IOWA

Report No. 29—MAHASKA COUNTY SOILS

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman and J. A. Elwell

Typical Mahaska county farmstead

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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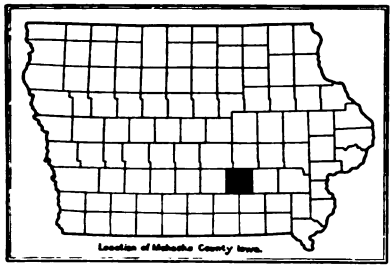
MAHASKA COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of L. W. Forman and J. A. Elwell

MAHASKA COUNTY is located in southern central Iowa in the third tier of counties north of the Missouri state line and in the fourth tier west of the Mississippi river, as shown in the accompanying map. It lies entirely within the Southern Iowa loess soil area and hence the soils of the county are mainly of loessial origin. There is only one type derived from glacial material and that has been formed by the washing away of so much of the surface covering of loess that the drift material makes up most of the three-foot soil section.



The location of Mahaska county.

The total area of Mahaska county is 568 square miles or 363,520 acres. Of this area 352,332 acres or 96.9 percent is in farm land. The total number of farms is 2,921 and the average size of the farms is 121 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the utilization of the farm land in the county.

Acreage in general farm crops	201,430
Acreage in pasture	120,949
Acreage in farm buildings, feed lots and public highways	13,729
Acreage in waste land	6,077
Acreage in crops not otherwise listed	898

THE TYPE OF AGRICULTURE IN MAHASKA COUNTY

The type of agriculture commonly followed in Mahaska county at the present time is general farming. It includes, therefore, the raising and feeding of livestock and the growing of hay and grain crops. Dairying is practiced to some extent but is not yet a very important industry commercially. The income on the farms is secured chiefly from the sale of livestock and the surplus corn, small grain and forage crops produced. Additional income is provided in some cases from the dairy products and from the sale of poultry and poultry products. The livestock industry is increasing and cattle feeding is becoming more important in the county. With this increase in cattle feeding and the even greater increase in the practice of hog raising, there is occurring a gradual decrease in the amount of the various crops which are sold to outside markets. The income from the dairy industry is increasing and there are now several creameries in operation in the county. Sheep raising is becoming more important and is providing considerable income on many farms. Fruit growing is practiced to some extent, but not on a commercial scale.

The area of waste land in the county is considerable and much of this land may be brought under cultivation and made quite as productive as the sur-

*Soil Survey of Mahaska County, Iowa, by E. C. Hall of the U. S. Department of Agriculture and J. A. Elwell of the Iowa Agricultural Experiment Station.

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TABLE I. ACREAGE YIELD AND VALUE OF CROPS GROWN IN MAHASKA COUNTY, IOWA*

Crop	Acres	Percentage of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	120,000	34.05	44.0	5,280,000	$0.30	$1,584,000
Oats	53,000	15.04	22.0	1,166,000	0.23	268,180
Winter wheat	6,500	1.84	21.0	136,500	0.90	122,850
Spring wheat	520	0.14	14.0	7,280	0.87	6,433
Barley	200	0.06	23.0	4,600	0.42	1,932
Rye	130	0.04	22.0	2,860	0.73	2,087
Potatoes	600	0.17	69.0	41,400	1.40	57,960
Tame Hay	20,100	5.70	1.4	28,140	9.08	255,511
Wild Hay	290	0.08	1.2	348	7.47	2,599
Alfalfa	90	0.02	3.75	338	12.92	4,366
Pasture	120,949	34.32	.....	.....	.....	.....

rounding territory if the soils are properly handled. In some instances the areas are in need of drainage and the installation of tile may be the only treatment necessary to bring the soil to a high state of fertility. In other cases the areas occur on the bottoms and are, therefore, subject to overflow. These areas may sometimes be reclaimed thru the straightening and deepening of the stream channels and subsequent drainage. They will then yield good crops in normal seasons. Some areas in the county consist of rather rough, broken land where the topography is steep and the soil is residual in origin. These areas are suitable only for pasture purposes, and sometimes not even for that. There are still other causes of infertility in soils and in a later section of this report special treatments will be suggested which are particularly desirable and most effective under individual soil conditions. In special cases for more or less abnormal conditions, advice regarding treatments may be secured from the Soils Section of the Iowa Agricultural Experiment Station.

THE CROPS GROWN IN MAHASKA COUNTY

The general farm crops grown in Mahaska county in the order of their importance are corn, oats, hay, wheat, potatoes, alfalfa, rye and barley. The acreage, yields and value of these crops grown in the county are given in table I.

Corn is the chief crop grown and it occupies the largest acreage and has the greatest value. In 1921, 120,000 acres, over one-third of the county, were devoted to this crop. Average yields secured amounted to 44 bushels per acre, but in many instances with favorable seasonal and soil conditions, yields are very much larger. Much of the corn produced on the farms is utilized for feed and the amount sold out of the county is decreasing as the livestock industries increase in importance. There are 213 silos in the county and a rather considerable amount of the corn produced is used for silage. The principal varieties grown are Reid's Yellow Dent, K. B. Yellow Dent, and Boone County White. Other varieties include Iowa Silver Mine, Johnson County White and Silver King. The corn is grown on sod or oat stubble and the land is usually plowed in the late summer or fall and disked in the spring. Cultivation is practiced three to five times, depending upon the seasonal conditions. Most of the crop is husked by hand. Some is cut and shocked in the field to be fed from the

*Iowa Yearbook of Agriculture, 1921.

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stalk or shredded; some is used for ensilage. Occasionally rape or cowpeas are seeded in the corn at the last cultivation and "hogged down" in the fall. This practice is of considerable value in building up the fertility of the soil.

Oats rank second in acreage and value and they are grown on practically every farm. In 1921, over 15 percent of the farm land in the county was devoted to this crop and average yields of 22 bushels per acre were secured. Much larger yields than this are secured under favorable soil conditions when the seasonal conditions are most satisfactory. The varieties commonly grown are the Iowa 103, Swedish Select, Early Champion and Kherson. The Iowa 103 oat has been found to be the most desirable variety for the county. The land is usually prepared for oats by disking and harrowing. Occasionally, however, it is plowed. The larger portion of the crop is used for feed and the straw serves for roughage and bedding. The surplus of oats is sold but the total amount sold out of the county is not large.

Hay is produced on a considerable area in the county and constitutes an important crop. Over 5 percent of the farm land is utilized for the production of tame hay which includes timothy, clover, bluegrass and other grasses. Average yields of the tame hay amount to 1.4 tons per acre. Some timothy is grown alone for seed and occasionally clover is grown for seed. They are sown in the spring with oats. Sometimes clover is utilized for pasture the first year and the second year the first crop is cut for hay and the second utilized for seed. Bluegrass grows well in the county and is used extensively for pasturage. Only a very small area is in wild hay and the amount produced is of little value.

Wheat, which is the next crop in value, is produced on a rather small acreage, amounting to less than 2 percent of the farm land in the county. Both winter wheat and spring wheat are grown, the area in the former being very much larger. Average yields of the winter varieties amount to 21 bushels per acre, while the spring varieties yield about 14 bushels per acre. The variety of winter wheat grown is Turkey, and spring varieties include Early Java, Bluestem and Marquis. Most farmers sell the entire wheat crop.

Potatoes are grown on most farms in the county and the total value of this crop is considerable. Early Rose, Early Ohio and Rural New Yorker are the main varieties produced. Practically all of the potatoes grown are utilized for home consumption.

Alfalfa is grown only on a small acreage at the present time, but it is becoming a more popular crop as farmers learn more of the methods of handling it and appreciate its value. Average yields of alfalfa are large and when the soils are limed, the crop inoculated, good seed used and the seed bed put in good condition, satisfactory yields of alfalfa may be secured on the main upland soils of the county.

Barley and rye are grown on small areas in the county and are of minor importance. Watermelons, muskmelons, cantaloupes, pumpkins and squash are grown on many farms for home consumption. Other crops of less importance are broom corn, peanuts, buckwheat, sweet potatoes, millet, rape and sorghum.

Fruit growing is not carried on in a commercial way, but there is a rather large acreage devoted to the production of fruit for local use. The principal

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varieties of apples grown are Baldwin, Jonathan, Willow Twig, Grimes, Ben Davis, Wealthy and Northwestern Greening. Cherries, strawberries, grapes, raspberries and blackberries are grown on small areas and are utilized for home consumption and for sale on the local markets.

MAHASKA'S LIVESTOCK INDUSTRY IS LARGE

The livestock industry of the county consists mainly of cattle feeding, cattle raising, hog raising and feeding, sheep raising and the raising of horses and mules. The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the livestock industries of the county:

Horses, all ages	13,491
Mules, all ages	1,619
Swine, on farms July 1, 1921	126,672
Swine, on farms Jan. 1, 1922	101,733
Cattle, cows and heifers kept for milk	10,342
Cattle, other cattle not kept for milk	27,392
Cattle, all ages	37,734
Sheep, all ages on farms Jan. 1, 1922	18,399
Sheep, shipped in for feeding, 1921	1,476
Sheep, total pounds wool clipped	126,583
Poultry, total number on farms Jan. 1, 1922	378,560
Poultry, number dozen eggs received 1921	1,712,171

Hog raising and feeding is perhaps the most important of the livestock industries in the county. Nearly every farmer feeds from 20 to 50 hogs and on the larger farms several hundred are raised each year. The principal breeds are the Duroc Jersey, Poland China, Chester White, Hampshire, Berkshire and Tamworth. The hogs are shipped to the packing plants at Ottumwa, Chicago, Minneapolis or Des Moines. The income from the sale of hogs is in excess of that from any of the other livestock industries. Cattle feeding is becoming of increasing importance thruout the county, and it is practiced to some extent on nearly all farms. The main breeds are the Angus, Hereford and Shorthorn. There are also many grades of these and other breeds. Cattle raising is practiced to some extent, and is particularly desirable on farms which include some of the rough land in the county. Sheep raising is becoming a rather important industry and increases the income of many farms. The Shropshire is the leading breed. Draft horses are raised on some farms, the Percheron being the most popular. Mules are raised in a few instances. Recently more attention has been given to the poultry industry; and while most farms raise enough poultry to supply the home demand, there has been an increasing sale of poultry and poultry products which adds materially to the income on many farms. Practically all of the eggs produced are sold in the local markets.

The value of land in Mahaska county is extremely variable, depending on the location with reference to railroad and market facilities and on the improvements on the farm, natural soil and topographic conditions. The average price of farm land at the time of the survey, 1919, ranged from $50 to $500 per acre. The latter figure represented a rather abnormal price for the best upland soils at the time of the survey. At present the upland soils will sell for $250 to $300 per acre. The poorer land and low-lying areas are of course, sold at lower figures.

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CROP YIELDS HAVE BEEN QUITE SATISFACTORY

The yields of general farm crops in Mahaska county, as shown by the figures given earlier in this report, have been quite satisfactory, particularly on the upland soils. There are many cases, however, where more profitable yields might readily be secured thru the adoption of better methods of handling the soils. In some cases drainage conditions are not entirely satisfactory, and when this is true tile should be installed if profitable crop yields are to be secured. In a few instances the soils are subject to serious washing and the adoption of methods of control of erosion are very necessary if satisfactory yields are to be accured and the soils kept fertile. On the rougher areas the land should probably be kept in pastures in order to prevent erosion.

MOST OF MAHASKA COUNTY SOILS ARE ACID

Practically all of the soils in the county are acid in reaction and applications of lime are necessary if satisfactory crop yields, particularly of legumes, are to be secured. There is no lime present in any of the surface soils on the uplands and only in one case is there lime in the lower soil layer and in that one instance the amount of lime present is small and the type will soon be in need of liming. Most of the bottomland soils are likewise acid in reaction and only in two cases is there any indication that lime is not needed. All of the upland soils in the county, therefore, and most of the bottomland types, should be tested for lime requirement. This material should be applied in the proper amounts if satisfactory crops are to be secured. Tests are necessary at regular intervals and the application of lime when needed is made preferably preceding the legume crop of the rotation.

The soils of the county in general are not very well supplied with organic matter and neither are they strikingly deficient. The Knox fine sand is very low in organic matter, as is also the Sarpy fine sandy loam on the bottoms. The majority of the upland types, however, are fairly well supplied with organic matter and dark in color.

The application of farm manure is of large value on all the soils of the county. Even the darker colored, apparently richer soils seem to be made more productive when farm manure is applied. On the light colored soils heavier applications of manure prove distinctly profitable. The beneficial effects of manure make its use desirable on all the soils and there is very little danger of making too large an application. Only on the Grundy soils should precaution be taken to apply the manure in smaller amounts, and at points in the rotation other than preceding the oats crop, to avoid the danger of lodging. The proper use of manure will aid materially in keeping up the organic matter content of the soils. All crop residues should also be used for this purpose and where farm manures are not available in sufficient amounts, leguminous crops should be utilized as green manures to maintain the supply of organic matter. By the proper use of farm manures, leguminous green manures and crop residues, the nitrogen content of the soils, as well as the organic matter supply, may be maintained much more readily.

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PHOSPHORUS CONTENT OF SOILS IS LOW

The phosphorus content is low in practically all the soils in the county and hence it is evident that phosphorus fertilizers, if not of value at the present time, will certainly be needed in the near future. There are many instances when phosphorus would probably prove of value on the soils of this county, and the greenhouse experiments and field tests on similar types in other counties indicate that profitable returns may frequently be secured from the use of phosphorus fertilizers. Farmers are urged to test rock phosphate and acid phosphate on their own soils at the present time in order to choose that material which will give the best returns. Field experiments now under way will permit of the making of a choice between these two materials in the future, but at present definite results can only be secured by tests on the individual farm.

THE GEOLOGY OF MAHASKA COUNTY

The native rock material underlying the soils of Mahaska county is buried under heavy deposits of glacial drift and loess and so rarely is there any exposure of these rocks that they have practically no effect upon the soil conditions of the county. There is only one soil derived from this bedrock material, and this type is known as the Union silt loam. It occurs only in narrow strips along deep drainageways, ravines, and the steep slopes, where the surface covering of drift and loess have been almost entirely washed away. The type is of practically no significance agriculturally.

During the glacial age a great sheet of ice known as the Kansan glacier spread over the entire area of the county and, upon its retreat, left behind a deposit of glacial debris or drift varying in depth from a few feet to several hundred feet. This Kansan drift is composed of bluish, gritty clay, sand, gravel and boulders. Originally it was a bluish-drab in color, but thru aeration and oxidation, this color has been changed to yellow or brown. Small boulders are found commonly thruout the drift deposit. The only soil type in the county which is derived from this Kansan drift is called the Lindley silt loam. It occurs where the loessial covering has been partially washed away along steep slopes and bordering deep valleys. The type is composed of a thin layer of loess, with the drift material making up a large part of the soil section.

At some later geological time, a covering of wind-blown material known as loess was laid down over the entire surface of the county. The original depth of this silty material varied from 10 to 20 feet and it contained about 75 per cent silt. It ranges in color from a light grayish-brown to yellowish-brown in its unchanged condition. After it has been exposed to weathering and to the accumulation of organic matter thru a long period of time, the color has become darker and ranges from a yellow to a dark brown or black. The original content of lime and other soluble salts has been washed away and there has been some accumulation of finer clay particles from the surface in a subsurface layer, and a still greater accumulation in the subsoil. Much of the glacial covering has been washed from the surface of the land and the depth of the loess mantle ranges now from a few inches to about 12 feet, depending to a large extent upon the topographic condition. The Grundy, Tama, Clinton and

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er extent and the topography is more or less rolling to gently rolling. The northwestern portion of the county, particularly in Richland township, resembles more closely the topographic features in the southwestern and northeastern sections and is distinctly rough. In the southeastern part of the county the topography is smoother and more gently rolling. The slopes are long and gentle and the divides between the streams are broader. In general the topographic features of Mahaska county vary from steep, broken and hilly in places to rolling or gently rolling thruout the major portion of the upland plains.

The drainage of the county is brought about by the North Skunk river, the South Skunk river, the Des Moines river and their tributaries. The North Skunk river crosses the county in the northeastern part and the chief tributaries are Buck creek, Moon creek, Pleasant creek, Cedar creek and Middle creek, the latter flowing diagonally across the county, almost parallel to the river and joining it almost at the county line. The valley of this river is comparatively wide, averaging about three-fourths of a mile in width. The tributaries flow thru narrow bottomlands and are bordered by much wider belts of eroded upland.

The South Skunk river, the second largest stream in the area, flows southeasterly across the county entering from the west at a point three miles south of the northern county line. It is approximately 43 miles in length in the county, but the course of the river is now being straightened from the Marion county line to a point about one-fourth mile north of the Chicago, Rock Island and Pacific railway bridge between Oskaloosa and Rose Hill which will shorten the length of the river considerably. The bottomland along this river varies from one-fourth mile to one and three-fourths mile in width, averaging about three-fourths of a mile to one mile. The largest tributaries of the South Skunk river are Buckley and Ballinger creeks and Maddox Branch. This river with its tributaries brings about the drainage of the entire central portion of the county.

The Des Moines river is the largest stream in the county, crossing the county diagonally in the southwestern townships, passing thru Scott, Jefferson, East Des Moines and West Des Moines townships. The bottomland along the Des Moines river varies from three-fourths mile to two miles in width, averaging about one and one-fourth miles. The largest tributary of the Des Moines river is Muchakinock creek. Other important tributaries are Cedar, St. Joseph, Bluff and Coal creeks. This river with its tributaries brings about the drainage of the southwestern portion of the county. The southeastern corner is drained by Cedar creek.

The natural drainage system of Mahaska county is quite complete. The larger streams with their tributaries extend into practically all parts of the county. With the exception of Cedar creek in the southeastern part, practically all of the streams have cut deep valleys and are still increasing in depth. The Des Moines river channel is 100 to 175 feet lower than the upland plain while the North and South Skunk rivers have channels from 90 to 150 feet below the upland plain. There is sufficient flow, therefore, to carry drainage water from the upland areas between the various streams and only in a few instances is

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there any necessity for the installation of artificial drainage. The southeastern corner of the county which is more level and less well drained, contains several areas of Grundy silty clay loam which is a poorly drained soil. There are some areas in the Grundy silt loam on the upland in various parts of the county that would be benefitted by tiling. The Calhoun silt loam, Bremer silt loam and Bremer silty clay loam on the terraces are frequently in need of artificial drainage and the Wabash soils of the bottoms may occasionally be benefitted by artificial drainage.

THE SOILS OF MAHASKA COUNTY

The soils of Mahaska county are grouped into five classes according to their origin and location. These are drift soils, loess soils, terrace soils, swamp and bottomland soils and residual soils. Drift soils are formed from materials carried by glaciers and deposited on the surface of the land when the glacier retreated. Loess soils are fine dustlike deposits made by the the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a deepening of the river channels. Swamp and bottomland soils are those occurring in poorly drained areas and along streams, and are subject to more or less frequent overflow. Residual soils are formed from the underlying rock material and remain resting upon it. The extent and occurrence of these groups of soils are shown in table II.

By far the largest portion of the county is covered by the loess soils, 76.9 percent. There is only one drift soil and it is of minor importance, covering 4.0 percent of the total area. The terrace soils are more extensive, the total area included in these soils amounting to 5.0 percent of the county. Swamp and bottomland soils occur more extensively and cover 12.9 percent of the county. There is one residual soil, covering 1.2 percent of the total area.

There are 22 individual types in the county and these together with the colluvial phase of the Wabash silt loam and riverwash make a total of 24 separate soil areas. There is one drift soil, six loess soils, eight terrace types, eight areas of swamp and bottomland soils, and one residual soil. These various soil types are distinguished on the basis of certain definite characteristics, which are described in the appendix of this report. The areas of the various soil types are given in table III.

The Clinton silt loam is the largest individual soil type in the county as well

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN MAHASKA COUNTY

Soil Group	Acres	Percent of total area of county
Drift soil	14,848	4.0
Loess soils	279,360	76.9
Terrace soils	18,240	5.0
Swamp and bottomland soils	46,528	12.9
Residual soils	4,544	1.2
Total	363,520	

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TABLE III. AREAS OF DIFFERENT SOIL TYPES IN MAKASKA COUNTY, IOWA

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOIL		
32	Lindley silt loam	14,848	4.0
	LOESS SOILS		
80	Clinton silt loam	121,472	33.4
120	Tama silt loam	81,344	22.4
64	Grundy silt loam	73,728	20.3
33	Knox fine sand	1,216	0.3
115	Grundy silty clay loam	1,024	0.3
66	Putnam silt loam	576	0.2
	TERRACE SOILS		
88	Bremer silt loam	7,296	2 0
75	Waukesha silt loam	5,248	1.4
81	Jackson silt loam	3,008	0.8
42	Calhoun silt loam	896	0.2
43	Bremer silty clay loam	640	0.2
38	Buckner loam	640	0.2
131	Judson silt loam	256	0.1
118	Plainfield loamy fine sand	256	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	25,088)	9.2
26a	Wabash silt loam (colluvial phase)	8,320)	
48	Wabash silty clay loam	7,040	1.9
71	Genesee silt loam	2,816	0.8
89	Sarpy silt loam	2,048	0.6
91	Sarpy loam	576	0.2
102	Sarpy fine sandy loam	320	0.1
53	Riverwash	320	0.1
	RESIDUAL SOIL		
157	Union silt loam	4,544	1.2
	Total	363,520	—

as the largest loess soil, covering one-third of the total area, 33.4 percent. The Tama silt loam is the second largest soil type and the second most extensive loess soil, covering 22.4 percent of the county. The Grundy silt loam is slightly smaller, covering 20.3 percent. The three remaining loess soils are all very minor in extent, covering less than one-half percent of the total area. The Lindley silt loam, the only drift soil in the county is minor in area, covering 4.0 percent. The terrace soils are all small in extent, the Bremer silt loam, the largest, covering but 2.0 percent. The Waukesha silt loam which is next, covers 1.4 percent. The remaining types are all small in area. The Wabash silt loam, the largest bottomland soil, together with the colluvial phase, which is much less extensive, covers 9.2 percent. The Wabash silty clay loam, the second largest bottomland soil, covers 1.9 percent. The remaining types are all small in area and cover less than 1 percent of the county. The Union silt loam, the only residual soil in the county, covers 1.2 percent of the area.

The topographic features of the uplands of the county are rather closely related to the soil types occurring on them. The Lindley silt loam is characterized by a steep to broken topography. The Clinton silt loam occupies rolling to rough areas and only infrequently occurs in level areas. The Grundy soils are more level, and the silty clay loam is found in flat or almost depressed areas. The Knox fine sand is rough in topography while the Putnam soils occur on more level areas in association with the Grundy soils. The terrace soils

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are all rather level in topography but the soils of the Bremer and Calhoun series are more depressed than the soils of the Buckner, Judson, Jackson and Waukesha series. The bottomland soils are all level in topography and the types of the Wabash series are particularly in need of drainage. The Union silt loam, the only residual type in the county is found on very rough broken land and presents the most striking topographic features.

THE FERTILITY OF MAHASKA COUNTY SOILS

Samples were taken for analyses from each of the soil types in Mahaska county, except the areas of Plainfield loamy fine sand, Union silt loam and riverwash. The first two of these soils are of such minor occurrence and so unimportant agriculturally, that they were not sampled for analyses. Riverwash is so variable in composition that analyses would mean practically nothing. The more extensive soil types were sampled in triplicate but only one sample was taken in the case of the minor types. The samples were all taken with the utmost care that they should represent the particular soil types and that variations due to local conditions and previous treatments should be eliminated. Samples were drawn at three depths, 0 to 6 2-3 inches, 6 2-3 to 20 inches, and 20 to 40 inches, representing the surface soil, the subsurface soil, and the subsoil respectively.

The total phosphorus, total nitrogen, total organic carbon and inorganic carbon content of the soils were determined and the limestone requirement was also estimated. The determinations of phosphorus, nitrogen, and carbon were made according to the official methods. The Truog qualitative test was used in determining the limestone requirement. The figures given in the tables are the average of the results of duplicate determinations on all samples of each type. They represent, therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre.

There is a rather wide variation in the total phosphorus content of the various soil types in the county, the amount present ranging from 660 pounds in the Lindley silt loam and the Jackson silt loam up to 2195 pounds in the Sarpy loam. No definite relations are apparent between the phosphorus content of the soils and the various soil groups, altho the average of the bottomland types is somewhat higher than that for the other groups. This might be expected inasmuch as the bottomland soils have been cropped to a less extent and there has been less removal of the element. The terrace soils average slightly higher than the loess types but the difference is not great. There is only one drift soil in the county, the Lindley silt loam and this is very low in phosphorus, as has been noted. No comparisons could be made because no other drift types were found. There are some rather wide variations within the various soil groups and in fact, these variations are somewhat greater than the variations between groups.

There is some relation evident between the phosphorus content of the individual soils and the soil series or particular type, thus the Clinton and Putnam

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TABLE IV. PLANT FOOD IN MAHASKA COUNTY, IOWA, SOILS

Pounds per acre of two million pounds of surface soil (0-6 2-3")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone Requirement
	DRIFT SOIL					
32	Lindley silt loam.....	660	2,120	27,846	0	3,000
	LOESS SOILS					
80	Clinton silt loam.....	982	2,200	31,158	0	3,333
120	Tama silt loam	1,107	3,526	45,718	0	5,666
64	Grundy silt loam.....	1,279	4,486	70,634	0	5,666
33	Knox fine sand	942	720	10,592	0	6,000
115	Grundy silty clay loam..	1,320	5,480	78,078	0	2,000
66	Putnam silt loam	969	2,840	34,944	0	6,000
	TERRACE SOILS					
88	Bremer silt loam.....	1,266	4,360	54,054	0	6,000
75	Waukesha silt loam	1,508	4,020	53,671	0	6,000
81	Jackson silt loam	660	2,400	29,721	Trace	0
42	Calhoun silt loam.....	1,589	4,300	52,470	0	5,000
43	Bremer silty clay loam..	1,630	3,640	47,338	0	6,000
38	Buckner loam	1,144	1,440	19,926	0	2,000
131	Judson silt loam	1,414	3,620	49,140	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,736	3,020	38,493	0	2,000
26a	Wabash silt loam (colluvial phase)	1,293	5,260	71,526	0	6,000
48	Wabash silty clay loam..	1,454	3,740	48,539	0	2,000
71	Genesee silt loam	1,817	3,360	37,947	0	4,000
89	Sarpy silt loam	1,481	2,620	29,983	920	0
91	Sarpy loam	2,195	2,000	22,700	1,760	0
102	Sarpy fine sandy loam...	942	720	9,445	0	2,000

silt loams are lower in phosphorus than the Tama and Grundy soils. The Bremer and Waukesha soils on the terraces are higher than the Buckner and Jackson soils. The Wabash soils are ordinarily richer than the Sarpy soils but the Sarpy loam in this county or at least the sample taken contained more phosphorus than any of the Wabash samples. Most of the soils are silt loams and hence comparisons of the phosphorus content of soils of different texture are not possible except in a few instances. The Grundy silty clay loam is higher than the Grundy silt loam and the Bremer silty clay loam contains more phosphorous than the Bremer silt loam, but the Wabash silty clay loam is not as well supplied as the silt loam. In general it would be expected that the silty clay loams would be richer than the silt loams. The Sarpy fine sandy loam is lower in phosphorus than the other soils of the same series. The loam seems to be higher than the silt loam, but as noted above this seems to be a somewhat abnormal soil. Ordinarily the silt loam would be richer than the loam. The Knox fine sand on the upland is lower in phosphorus than would be expected and in general the results seem to indicate that coarse textured soils are not usually as well supplied with phosphorus as is the case with the finer textured soils. This is true when soils of different textures in the same series are concerned, and very often it is the case also when soils in different series are compared. Some soil series are so entirely different in characteristics from others, that comparisons between series should not be made without giving rather definite information regarding the characteristics of the series involved.

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In general the results seem to indicate that the phosphorus supply in the soils of Mahaska county is not large in any case. While it is not strikingly deficient in some instances, in practically all cases the supply is too low for a continued production of available phosphorus sufficient to keep crops supplied for more than a very few years. It is quite evident that phosphorus fertilizers should give beneficial effects at the present time in many cases.

The total supply of phosphorus in soils does not indicate how much will be made available for crop use in any one season but when the total amount is low it may be rather positively concluded that there will be an insufficient production of the element in an available form. If the supply is large there is more chance for an adequate production of available phosphorus, but the amount produced cannot be determined definitely. In the soils of Mahaska county, therefore, where the total content is low, it is very reasonable to conclude that phosphorus fertilizers may be of value in many cases at the present time because of the probable need of available phosphorus. As will be noted later, phosphorus applications have been found to be of value in many instances and while definite recommendations cannot be made at this time, it is urged that farmers test the use of various phosphorus fertilizers on their own soils and thus determine for their own conditions which material would prove the most profitable.

In nitrogen content the soils of the county are even more variable than in phosphorus. The total amount ranges from 720 pounds in the Knox fine sand and the Sarpy fine sandy loam up to 5,480 pounds in the Grundy silty clay loam. There is no relation apparent between the nitrogen content of the various soil groups and the variations within groups are much larger than the variations between groups. The relation of nitrogen content to texture is evidenced in the few instances where the textures of the soils vary. Thus the two types mentioned above, which are the lowest in nitrogen, are a fine sand and a fine sandy loam. The Buckner loam and the Sarpy loam are lower in nitrogen than any of the silt loams which is the predominating texture of the soils in the county. The Grundy silty clay loam is higher than the Grundy silt loam but the reverse is true in the case of the Bremer soils.

There are some interesting relations evident also between the various silt loams. Thus the Grundy and Tama silt loams on the uplands are higher than the Clinton and Putnam silt loams. The Bremer and Waukesha are higher than the Jackson and Judson silt loams on the terraces. The Wabash silt loam contains more nitrogen than the Genesee or Sarpy on the bottoms. These are evidences of the variations in some of the characteristics upon which the differentiation of the soil series is based. There is some relation also between the nitrogen content of the soils and their topographic position. Thus the Grundy and Tama soils on the upland and the Bremer and Waukesha on the terraces are more level in topography than the other types with which they are compared. This topographic condition is another factor upon which the soil series are separated. In general it may be said that soils heavy in texture and level to depressed in topography ordinarily will contain more nitrogen and will be classified in series which include the darker colored soils.

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The analyses indicate that the soils of the county with the exception of the two sandy types are fairly well supplied with nitrogen. In spite of this fact, nitrogen must not be disregarded in planning systems of permanent fertility. If the nitrogen content of the soil is to be kept up, some material supplying this element must be applied at regular intervals. Farm manure is the commonest material utilized to maintain nitrogen in the soil and it has a large fertilizing value because of its nitrogen content. Beneficial effects of farm manure are not restricted, however, to the soil types which are lowest in nitrogen but will be evidenced even on those types which are apparently well supplied. While the largest influence will appear on sandy soils considerable crop increases are secured when this material is applied to such types as the Grundy silt loam, Tama silt loam and Grundy silty clay loam. In these cases, however, smaller applications may be made with beneficial effect.

The proper use of crop residues on the farm also aids materially in keeping up the nitrogen content of the soil. When farm manure is not available for use, as on the grain farm or where there is an insufficient production to make applications to all the land on the farm, well inoculated leguminous crops should be utilized as green manures. When well inoculated, legumes make use of the free nitrogen of the atmosphere and hence they may serve to increase the nitrogen content of the soil provided a part or all of the crop is turned under in the soil. If a legume is removed from the soil there will be no increase in nitrogen, as in the average soil the amount of nitrogen contained in the roots of the legumes is about equivalent to that taken from the soil. To keep up the nitrogen content in the soils of Mahaska county, therefore, there should be a thoro utilization of all the farm manure and crop residues and leguminous crops should be turned under as green manures.

The organic carbon content of soils indicates the amount of organic matter present. The color of the soil also indicates the organic matter content. Black soils are high in organic matter, while light colored soils are apt to be lacking in organic matter. Furthermore, there is a definite relation between the organic carbon in soils and the nitrogen present. Hence the color of the soil indicating the organic matter supply will also indicate the supply of nitrogen and vice versa. There is a wide variation in organic carbon in the soils of Mahaska county, the relations between the soil types in content of this constituent being very much the same as in the case of nitrogen. The sands are the lowest and the loams are higher than the sandy types and contain less organic matter than the silt loams. The silty clay loams are occasionally higher than the silt loams. Very similar relations between organic carbon and the individual soil series are shown as were noted in the case of nitrogen and in general, it seems that the soils which are level to depressed in topography and finer in texture are richer in organic matter.

The relation between the carbon and nitrogen in soils indicates quite definitely the rate at which plant food is being made available. There seems to be a rather satisfactory relation between these two constituents in the soils of Mahaska county, altho in some instances the relations are more satisfactory than in others. The beneficial effect of manure is particularly evidenced on those

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soils in which the relation is not quite so good. This is due to the fact that manure stimulates bacterial activities and indirectly increases the production of available plant food. Where the carbon-nitrogen relation is not at the best, there will be an insufficient production of available food constituents.

In all the soils of the county the organic matter supply must be maintained. Farm manure, crop residues, and leguminous crops must be utilized for this purpose. None of the soil is extremely high in organic matter and under continued cultivation and drainage there is a constant removal of this material. On the sandy types the supply must be built up by especially large additions of organic materials, while on the other types, normal applications should be made in order to prevent the soils from becoming infertile due to lack of organic matter.

Only two of the soils in the county show any content of inorganic carbon and in neither case is the amount large. These two types, both in the Sarpy series, and the Jackson silt loam, are the only ones which do not show a lime requirement. The amount of lime needed is indicated roughly in the figures given in the table. These figures should not be considered to show definitely the amount of lime which should be applied to any particular soil. Soils vary widely in lime requirement and before an application is made the individual soil should be tested. The figures do serve to show, however, that practically all the soils of the county are acid in reaction and need applications of lime if crop growth, particularly of legumes, is to be satisfactory. Even in those cases where there is a small amount of inorganic carbon, lime will be needed in the future as the amount present in the soil will be washed away rather rapidly. All the soils of the county, therefore, should be tested and lime applied when needed.

THE SUB-SURFACE SOILS AND THE SUBSOILS

The results of the analyses of the subsurface soils and the subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of subsurface soil and 6,000,000 pounds of subsoil per acre. The plant food present in the lower soil layers has comparatively little effect on the fertility of the soil unless the amount present is very large. The analyses of the surface soils, therefore, usually indicate fairly definitely the needs of the soil and the conclusions drawn will not be largely modified by a detailed study of the analyses of the lower layers.

The subsurface soils and subsoils of Mahaska county are not rich in any of the plant food constituents, in general they are not as high as the surface soils and hence the fertility of the soils is not affected to any large extent by the subsoil conditions. The analyses of these lower soil layers need not be considered in detail and it may merely be noted that they serve to confirm the conclusions drawn from the results of the analyses of the surface soils. The phosphorus supply is low and phosphorus will be needed in the near future and might probably prove of value in many cases at the present time. The nitrogen and organic matter supply is not low except in one or two instances but the soils will respond to applications of farm manure and this material together with crop residues and leguminous green manures must be utilized if the nitrogen and organic matter supply is to be kept up. There is no large content of lime in the lower soil layers of any of the types and hence it is necessary that the soils be

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TABLE V. PLANT FOOD IN MAHASKA COUNTY, IOWA, SOILS
Pounds per acre of four million pounds of subsurface soil (6 2-3"-20")

Soil No.	Soil Type	Total Phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOIL					
32	Lindley silt loam	996	1,440	19,765	0	7,000
	LOESS SOILS					
80	Clinton silt loam	1,687	2,040	23,514	0	5,333
120	Tama silt loam.....	1,805	4,040	51,578	0	5,333
64	Grundy silt loam	1,877	4,453	66,247	0	4,333
33	Knox fine sand.....	1,508	880	16,926	0	5,000
115	Grundy silty clay loam..	2,398	5,920	91,676	480	0
66	Putnam silt loam	1,186	2,320	30,685	0	6,000
	TERRACE SOILS					
88	Bremer silt loam.....	1,912	5,120	67,704	0	6,000
75	Waukesha silt loam.....	1,778	4,240	60,606	0	6,000
81	Jackson silt loam.....	1,186	1,760	20,202	0	5,000
42	Calhoun silt loam.....	1,562	2,240	33,852	0	6,000
43	Bremer silty clay loam..	2,926	4,240	62,790	0	6,000
38	Buckner loam	2,370	3,360	54,927	0	3,000
131	Judson silt loam.....	2,828	6,480	89,544	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam.....	2,990	6,360	69,888	0	2,000
26a	Wabash silt load (colluvial phase)	1,912	5,600	92,274	0	6,000
48	Wabash silty clay loam..	3,016	6,360	85,722	0	4,000
71	Genesee silt loam.....	2,478	4,240	48,594	0	4,000
89	Sarpy silt loam.....	2,478	4,800	52,894	1,160	0
91	Sarpy loam	2,828	2,800	28,458	480	0
102	Sarpy fine sandy loam...	1,940	1,120	12,012	0	2,000

tested for lime requirement and that this material be applied when they are acid. The types which showed some inorganic carbon in the surface soil contain very similar amounts in the lower soil layers and two other types, the Grundy silty clay loam and the Sarpy fine sandy loam, show a small amount of lime at the lower depths. The supply is too small, however, to be significant and under adequate drainage conditions the amount present will soon be exhausted. All the soils of the county should be tested for lime requirement regardless of any small supply in the subsoil.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Mahaska county in order to gain some indications of the fertilizer needs of the soils and to determine the possible value from the application of certain fertilizing materials. The Grundy silt loam and the Tama silt loam, two of the most important types in the county, were used. In addition, greenhouse experiments on the Clinton silt loam from Wapello county are included, inasmuch as this is a very important type in Mahaska county and the results secured in the other county would indicate very definitely the results which may be secured in Mahaska. Experiments on the Grundy silt loam from Wapello county and on the Tama silt loam from Black Hawk county are also given as these types occur extensively in Mahaska county.

The treatments used in all the experiments include manure, lime, rock phosphate, acid phosphate, and a complete commercial fertilizer. These ma-

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Fig. 2—Clover pot culture on Grundy silt loam. Lime with manure produced a substantial increase, as did also both the rock and acid phosphates.

terials were applied in the same amounts in which they are used in field experiments and in practice and hence the results of these greenhouse tests may be considered to indicate quite definitely the results which may be secured in the field. Manure was added at the rate of 8 tons per acre, lime in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate was used at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete com-

TABLE VI. PLANT FOOD IN MAHASKA COUNTY, IOWA, SOILS
Pounds per acre of six million pounds of subsoil (20"-40")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOIL					
32	Lindley silt loam.....	1,536	840	13,595	0	9,000
	LOESS SOILS					
80	Clinton silt loam.....	2,680	1,940	23,860	0	7,000
120	Tama silt loam.....	2,774	3,500	45,427	0	5,666
64	Grundy silt loam.....	2,438	3,680	48,255	0	1,666
33	Knox fine sand	1,536	1,320	22,113	0	3,000
115	Grundy silty clay loam.	2,547	3,360	50,397	1,200	0
66	Putnam silt loam.....	2,142	3,840	45,700	0	5,000
	TERRACE SOILS					
88	Bremer silt loam.....	1,899	3,180	38,984	0	6,000
75	Waukesha silt loam....	2,466	3,180	39,312	0	6,000
81	Jackson silt loam.....	1,818	2,340	27,027	0	7,000
42	Calhoun silt loam.....	1,980	1,680	33,906	0	5,000
43	Bremer silty clay loam..	3,555	5,700	82,719	0	5,000
38	Buckner loam	3,354	4,860	54,054	0	3,000
131	Judson silt loam.....	3,432	7,200	103,849	0	6,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam.....	3,474	6,540	75,348	0	3,000
26a	Wabash silt load (colluvial phase)	2,343	2,640	56,019	0	5,000
48	Wabash silty clay loam..	3,597	5,700	76,658	0	2,000
71	Genesee silt loam.....	3,030	4,680	52,416	0	6,000
89	Sarpy silt loam.....	3,840	3,000	26,496	1,350	0
91	Sarpy loam	2,586	2,340	28,076	1,080	0
102	Sarpy fine sandy loam..	2,304	720	6,891	480	0

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TABLE VII. GREENHOUSE EXPERIMENT, GRUNDY SILT LOAM, MAHASKA COUNTY

Pot No.	Treatment	Green Weight Clover in Grams
1	Check	70.30
2	Manure	81.64
3	Manure+Lime	111.13
4	Manure+Lime+Rock phosphate	120.02
5	Manure+Lime+Acid phosphate	124.74
6	Manure+Lime+Complete commercial fertilizer	104.32

mercial fertilizer at the rate of 300 pounds per acre. Wheat and clover were grown in the experiment, the clover being seeded about one month after the wheat was up. Only the clover yields are given in the results on the Grundy silt loam and Tama silt loam from Mahaska county as the wheat yields were not secured. The yields of both crops are given in the other tests.

RESULTS ON GRUNDY SILT LOAM

The results secured in the experiment on the Grundy silt loam from Mahaska county are given in table VII, the yields being shown as green weights of clover only. Manure brought about a distinct increase in the clover and the application of lime with the manure had an additional effect which was very large. The acid phosphate and the rock phosphate both gave further increases, but the complete commercial fertilizer showed no effect. The beneficial effect of lime on clover grown on this soil is generally recognized among farmers and in-

Fig. 3—Tests on Grundy silt loam show the value of manure, lime and a phosphate fertilizer for wheat.

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TABLE VIII. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, MAHASKA COUNTY

Pot No.	Treatment	Green Weight Clover in Grams
1	Check	83.91
2	Manure	149.68
3	Manure+Lime	196.04
4	Manure+Lime+Rock phosphate	201.85
5	Manure+Lime+Acid phosphate	249.48
6	Manure+Lime+Complete commercial fertilizer	242.67

creases secured in the field are frequently quite as large as those shown here. The effects of manure are likewise generally recognized and this material is considered one of the best fertilizers for use on this soil. The possibility of securing profitable crop increases from the use of phosphorus on this soil is quite clearly shown by these results. No definite conclusions can be drawn regarding the relative value of the two phosphorus fertilizers, but the desirability of testing them under farm conditions is quite evident. Manure, lime and phosphorus are certainly the fertilizing materials needed on the Grundy silt loam in order to bring about better crop growth.

RESULTS ON TAMA SILT LOAM

The results obtained on the Tama silt loam from Mahaska county are shown in table VIII. Again only the green weights of clover are given. Manure gave a very large increase in the yield of clover and this increase is in accord with that secured in most instances on the farm. The application of lime along with manure brought about a further distinct increase in the clover and this also is in accord with the results secured in practice. Lime always proves profitable

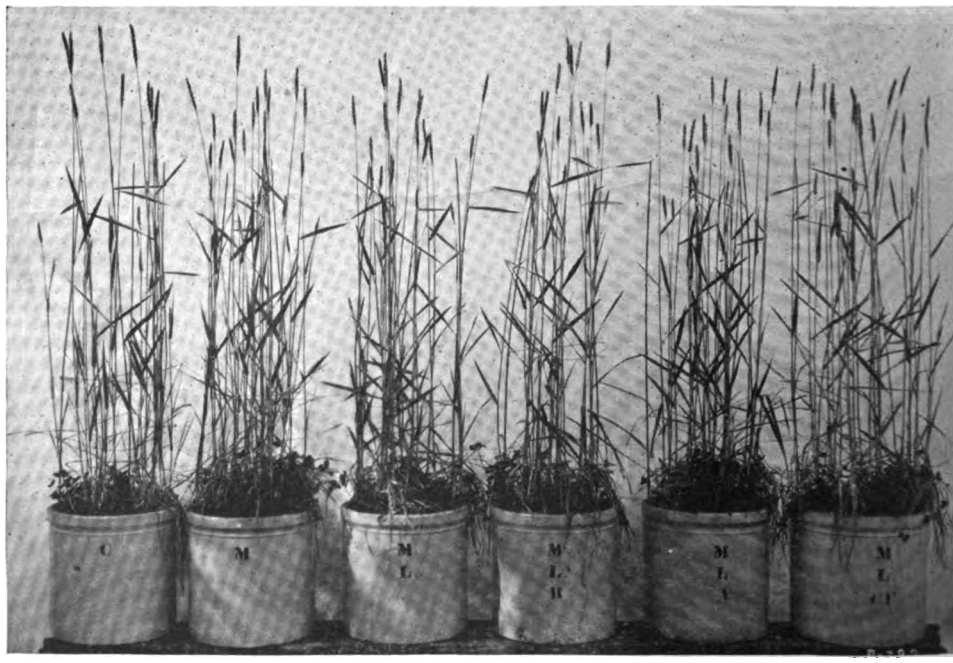

Fig. 4—Wheat and clover on Tama silt loam.

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Fig. 5—Clover pot culture on Tama silt loam.

for growing legumes on this type. The application of rock phosphate had some effect on the clover, but the increase was not nearly so large as that brought about by the use of acid phosphate. The complete commercial fertilizer gave an increase only slightly less than that of the acid phosphate. It seems evident that phosphorus fertilizers may be of considerable value on this type, and while definite conclusions should not be drawn from individual tests, these results would indicate that acid phosphate might prove profitable on this soil, and probably more profitable than rock phosphate. Apparently the Tama silt loam will respond to applications of manure, lime and phosphorus. Which phosphate fertilizer should be used should be determined by tests on the individual farms.

RESULTS ON CLINTON SILT LOAM

The results secured on the Clinton silt loam from Wapello county are shown in table IX. The addition of manure to this soil gave a slight increase in the yield of wheat but a very considerable gain in clover. When lime was applied with the manure, the yields of both crops were increased considerably, the effect being the greatest in the case of the clover. Rock phosphate increased the yield of wheat quite definitely and showed a very large effect on the clover. Acid phosphate and the complete commercial fertilizer gave increases in both crops which were almost identical, showing less influence on both the wheat and the clover, however, than that evidenced by the rock phosphate. It is evident from these results that manure is a particularly valuable fertilizer on the Clin-

TABLE IX. GREENHOUSE EXPERIMENT, CLINTON SILT LOAM, WAPELLO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	21.0	31.7
2	Manure	22.0	47.6
3	Manure+Lime	26.5	54.3
4	Manure+Lime+Rock phosphate	30.7	67.9
5	Manure+Lime+Acid Phosphate	30.5	58.8
6	Manure+Lime+Complete commercial fertilizer	30.7	58.9

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TABLE X. GREENHOUSE EXPERIMENT, GRUNDY SILT LOAM, WAPELLO COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	18.1	33.0
2	Manure	17.8	34.0
3	Manure+Lime	18.4	37.0
4	Manure+Lime+Rock phosphate	24.4	48.0
5	Manure+Lime+Acid phosphate	18.2	55.0
6	Manure+Lime+Complete commercial fertilizer	21.1	38.0

ton silt loam. Lime should be applied in addition to manure if satisfactory legume growth is to be secured, and increases will follow its use. Phosphorus fertilizers will probably prove profitable on this type and tests on individual farms of the relative value of rock and acid phosphate should be carried out.

The results secured on the Grundy silt loam from Wapello county are given in table X. Manure brought about the same effect on the clover in this experiment but showed little influence on the wheat. Lime in addition to the manure gave increases in both crops, the effect being quite definite in the case of the clover. Rock phosphate showed a considerable increase in wheat and a very large gain in the clover. Acid phosphate had little effect on the wheat but increased the clover yields to a larger extent than did the rock phosphate. The complete commercial fertilizer increased the wheat yields but to a smaller extent than did the rock phosphate. The increase on clover was smaller than that

Fig. 6—Manure increased the wheat yield on the Clinton silt loam. Acid phosphate with manure increased the yield more noticeably than did the rock.

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Fig. 7—Clover pot culture on Clinton silt loam. Manure is of decided benefit. Rock and acid phosphate also proved of value, applied with manure.

brought about by either of the phosphorus carriers. These results very largely confirm those secured on the same type in Mahaska county and show the beneficial effect of manure, lime and phosphorus on this soil. Definite conclusions as to the comparative value of the two phosphorus carriers should not be drawn from these results, but they emphasize the need of testing these materials on individual farms and with various crops.

The results of the experiment on the Tama silt loam from Black Hawk county are given in table XI. The application of manure in this case had a slight effect on the wheat but increased the clover yield enormously. Lime applied with manure increased the wheat yields very slightly but gave a very large effect on the clover. Rock phosphate showed a distinct increase on the wheat and on the clover. Acid phosphate had less effect than the rock on the wheat but increased the clover to a much larger extent. The complete commercial fertilizer showed more effect on the wheat than did the acid phosphate but less than the rock phosphate, while in the case of the clover it had more effect than the rock phosphate but less than the acid phosphate. It is apparent from the results that manure is a particularly valuable fertilizer for use on this soil and that lime applied with manure is of large value in increasing clover yields. It exerts some effect also on the grain crops. Phosphorus fertilizers may be of considerable value on this soil and tests in the field should be carried out to determine whether rock phosphate or acid phosphate should be employed.

TABLE XI. GREENHOUSE EXPERIMENT, TAMA SILT LOAM, BLACK HAWK COUNTY

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+Lime	12.86	51 5
4	Manure+Lime+Rock phosphate	14.03	57.0
5	Manure+Lime+Acid phosphate	12.72	64.5
6	Manure+Lime+Complete commercial fertilizer	13.67	59.5

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These greenhouse experiments as a whole indicate that the Grundy silt loam, the Tama silt loam and the Clinton silt loam, the main types in Mahaska county, will respond to applications of manure, lime and phosphorus. Manure is the fertilizer of largest value that can be used. Lime proves distinctly profitable, especially because of its large effect on legume growth. Phosphorus fertilizers will undoubtedly be profitable on these soils in the field. Just which material should be used, whether rock phosphate or acid phosphate, must be determined by actual tests on the farm.

FIELD EXPERIMENTS

A field experiment has been laid out in Mahaska county but thus far results have not been secured and hence no data are available from field work in this county. The experiment must be carried on for a period of years before the results can be considered satisfactory for interpretation. There are several field experiments under way in other counties, however, which are located on some of the leading soil types in Mahaska county and the results secured on these fields are undoubtedly indicative of the results which will be obtained in Mahaska county. The effects of applications of various fertilizing materals are quite clearly shown in the results, and it seems quite reasonable to conclude that the same materials would bring about very similar results in Mahaska county on the same soil types.

The data included in this report have been secured on the Clinton silt loam in Scott county, the Grundy silt loam in Henry and Wapello counties and the Tama silt loam in Black Hawk county. These fields are all located on land which is thoroly representative of the individual soil types. Corner stakes are installed to show the location of the plots and care is used in applying fertilizers and in harvesting the crops and securing the yields so that the results obtained may be considered highly dependable.

Each series of plots includes tests under the livestock system of farming and under the grain system. Manure is applied in the former system while crop residues serve as a source of organic matter in the latter. Fertilizer treatments tested include limestone, rock phosphate, acid phosphate and a complete commercial fertilizer. The manure is applied at the rate of 8 tons per acre once in a four year rotation. Limestone is added in a sufficient amount to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre annually and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. In 1921 the standard brand employed was changed to conform to the new fertilizer standards and a 2-12-2 fertilizer is now being used on these plots at the rate of 267 pounds per acre annually. On the grain system plots, the second crop of clover is turned under, the corn stalks are cut with a disk and plowed under, and the threshed straw from the small grain is returned to the soil. These materials provide the crop residues. The series of plots consists of 13, 3 of which are untreated or check plots and are numbered 1, 7 and 13. Plots 1 to 7 are included in the livestock system while plots 7 to 13 are in the grain system.

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The experiment at Mt. Pleasant on the Grundy silt loam in Henry county was laid out in 1915 and the experiments in Scott, Wapello and Black Hawk counties were laid out in 1917. These plots are all 155′ 7″ by 28′, or one-tenth of an acre in size. On the Princeton, Mt. Pleasant and Agency fields, the complete data for the full series of plots is included. In the case of the Farson field and the Hudson field, however, only the results for the livestock system plots are given, inasmuch as the results on the crop residue plots are evidently abnormal. They have not yet received sufficient treatment to show any effects.

In addition to these individual results from the fields mentioned, tables are given showing average yields of various crops grown on all the experiment fields in the state on the Grundy silt loam and on the Tama silt loam. With the former type, the corn yields are the average of eleven yields on nine fields. The oats are the averages of six yields on four fields. Clover yields are averaged from ten crops on eight fields and the wheat from four crops on four fields. With the Tama silt loam the figures are the averages of three yields on two fields in the case of corn and of two crops on two fields in the case of the oats. These two latter tables show rather definitely the results which may be expected on these two types of soil from the treatments practiced, and as a whole they confirm the conclusions which may be reached from a consideration of the results on the individual fields.

THE PRINCETON FIELD

The results obtained on the Princeton field located on the Clinton silt loam in Scott county are given in table XII. The results shown in this table indicate the effect of fertilization on winter wheat, corn, oats and clover on this type. Some interesting effects of treatment are shown in the case of all the crops grown. Manure produced a considerable increase in the wheat, corn and oats and a large increase in the case of the clover. The application of lime with manure gave further increases in the case of all crops. Rock phosphate with lime and manure showed beneficial effects on the wheat, corn and clover, but had practically no effect on the oats. Acid phosphate with the lime and manure showed increases on the wheat, corn, oats and clover, the effect being smaller than that of the rock phosphate on wheat and corn but greater in the case of the oats and the clover. The differences are not large and definite conclusions as to the relative effects of these two materials should not be drawn. The complete commercial fertilizer showed beneficial effects on the corn, oats and clover giving slightly larger returns than either the acid phosphate or the rock phosphate. No effect was evident on the wheat.

In the grain system the crop yields on the crop residue plots are not given for the years 1918 and 1919 as the yields were evidently not normal and there had been no additions. In the remaining years the results are shown and are practically duplicates of the check plots. Additions of lime had some effect on all the crops grown, the increase secured being very large in the case of the clover. Rock phosphate increased crop yields in every instance. Acid phosphate showed a larger effect than the rock in the case of one corn crop and in

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the case of the oats but had less effect on the wheat and clover, showing gains in every instance except one. The complete commercial fertilizer showed slightly larger increases in crop yields than either of the phosphates, but the differences were not large enough to be distinctive.

It is apparent from this experiment as a whole that manure is a particularly valuable fertilizer to use on the Clinton silt loam. Lime will bring about beneficial effects when the soil is acid and these effects may be quite pronounced in the case of corn and small grain crops as well as in the case of clover. There are indications of value from the use of phosphorus fertilizers applied with manure and lime. Complete commercial fertilizers seem to have insufficient effect to warrant their use in preference to phosphates. Just which phosphate should be employed must be determined for the individual farm conditions. The results are very similar in the case of the grain system, there being indications of value from liming and the use of phosphates.

THE MT. PLEASANT FIELD

The results secured on the Mt. Pleasant field are given in table XIII. The yields for the first two years of the experiment are not included because of very evident abnormality. The yields for the two duplicate series of plots for this field are given together in the table. The yields on the check plots in the case of the corn and oats are the averages of three checks, 1, 7 and 13. In the case of the clover crop the checks are averaged for the livestock system and the grain system separately. In the former, the total yields from both crops of clover on

TABLE XII. FIELD EXPERIMENT PRINCETON FIELD
Clinton Silt Loam—Scott County

Plot No.	Treatment	Winter Wheat bu. per A. 1918	Corn bu. per A. 1919	Corn bu. per A. 1920	Oats bu. per A. 1921	Clover tons per A. 1922
1	Check*	33.5	61.8	59.6	25.8	1.50
2	Manure	37.4	67.6	68.3	28.4	1.93
3	Manure+Lime	43.0	68.2	70.6	32.1	2.13
4	Manure+Lime+ Rock phosphate..	47.4	67.8	73.5	31.9	2.25
5	Manure+Lime+ Acid phosphate ..	45.2	64.0	70.8	35.1	2.29
6	Manure+Lime+ Complete commercial fertilizer.....	37.3	63.4	73.0	36.4	2.34
8	Crop residues	....**	....**	58.6	29.6	1.47
9	Crop residues+Lime	31.7	62.4	67.3	29.7	2.14
10	Crop residues+ Lime+Rock phosphate	35.0	64.1	68.7	29.8	2.28
11	Crop residues+ Lime+Acid phosphate	31.7	66.6	61.5	31.1	2.18
12	Crop residues+ Lime+Complete commercial fertilizer	36.2	65.2	69.5	30.8	....***

*The check plot yields in 1 are the averages of the yields on plots 1, 7 and 13.
**Yields not given because of very evident abnormality.
***Yield not secured.

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the three checks are averaged while in the grain system the check yield is the average of the first crop of clover on plots 7 and 13.

There are some variations in the results secured on this field and in certain years on individual plots the results appear to be somewhat abnormal. Thus in one or two instances, the effects of manure are not evident over the check plots but in general it may be said that the application of manure to this soil is very desirable and brings about a profitable increase in crop yields. This is certainly true when the results are averaged over the period of a rotation. On both the 100 and 200 series, the effects of manure may be considered as showing definite value. When lime was applied along with manure large increases were secured in crop yields in practically all instances. The effects are particularly noticeable in the case of the clover but large gains are shown also with the corn and oats. Apparently lime is of value on this type because of effects on all the crops of the regular four year rotation.

Rock phosphate showed large increases in the yields of the various crops, the influence being particularly evident in the case of the oats and clover. Acid phosphate also increased the yields of the various crops, in many instances showing larger effects than the rock phosphate. In a few cases, however, the reverse is true. The results would hardly permit of definite conclusions as to which material would be the most desirable, but they seem to indicate that over the six year period on this field, acid phosphate is somewhat preferable. The complete commercial fertilizer showed effects which were about the same on the average as those obtained with the acid phosphate. Apparently this material has no very pronounced superior effects over the acid phosphate.

In the grain system plots there has been some treatment with crop residues after the first few years of the experiment and there is evidence of increased yields due to the thoro utilization of the crop residues. Again lime brings about an increase in the yields of the crops grown altho in several instances the

TABLE XIII. FIELD EXPERIMENT, MT. PLEASANT FIELD
Grundy Silt Loam—Henry County

Plot No.	Treatment	1917		1918		1919		1920		1921		1922	
		100 Corn	200 Oats	100 Oats	200 Clover	100 Clover	200 Corn	100 Corn	200 Corn	100 Corn	200 Oats	100 Oats	200 Clover
1	Check	48.1	93.1	78.7	7883	8300	57.3	48.3	76.2	58.0	33.9	44.7	3.0
2	Manure	37.5	85.0	75.1	9650	7580	66.3	57.0	74.9	56.7	46.9	39.8	3.1
3	Manure+Lime	55.2	90.0	74.8	10600	7990	74.1	76.6	82.2	59.5	35.3	62.1	3.3
4	Manure+Lime+Rock phosphate	66.0	107.5	76.5	11450	9860	78.6	81.8	88.6	67.5	42.6	63.3	3.5
5	Manure+Lime+Acid phosphate	78.6	97.5	85.1	12575	12950	75.2	77.7	101.4	72.8	48.9	70.1	3.8
6	Manure+Lime+Complete commercial fertilizer	76.8	97.5	80.8	10850	13870	66.5	67.5	88.4	64.9	46.5	70.6	3.4
7	Check*	48.1	93.1	78.7	4575	4380	57.3	48.3	76.2	58.0	33.9	44.7	1.9
8	Crop residues	50.8	91.3	81.3	5650	4600	65.3	67.5	80.7	65.7	43.1	54.5	2.3
9	Crop residues+Lime	47.1	92.5	98.2	4250	4450	71.0	80.6	84.5	66.1	40.0	49.0	2.6
10	Crop residues+Lime+Rock phosphate	52.7	100.0	96.4	5985	5700	75.1	90.0	83.3	65.0	43.8	57.9	2.5
11	Crop residues+Lime+Acid phosphate	54.7	92.5	99.9	6545	6420	81.1	75.5	99.9	66.9	43.5	54.8	2.5
12	Crop residues+Lime+Complete commercial fertilizer	52.8	107.5	93.6	5390	6300	78.5	51.2	107.9	67.1	42.2	61.9	2.6

*The check yields given under 7 are the same as under 1 in the case of the corn and oats, the figures being the average of the three check plots. In the case of the clover in 1918 and 1919, however, the yields in 7 are the averages of the first clover crop on plots 7 and 13, the second crop being turned under on the crop residue plots. In 1922 only one crop of clover was secured. The clover yields in 1 are the averages of both clover crops on all three check plots.

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effects were not pronounced. In general the results are not nearly as definite as on the livestock system plots. Farm experience proves very definitely the desirability of liming this soil when it is acid. Rock phosphate and acid phosphate both gave considerable increases in yields of corn, oats, and clover, in all but one case. In several instances the acid phosphate seems to be somewhat superior to the rock and would average up somewhat better for the six year period. In general conclusions are rather difficult to draw and it should be emphasized that these two materials should be tested by individual farmers before a choice is made. The complete commercial fertilizer had effects which in general were very little greater than those produced by the phosphates, and hence it would seem that the phosphates would prove more economically desirable. It seems evident that on the Grundy silt loam manure is a valuable fertilizer, lime should be applied and there is rather distinct evidence that a phosphorus fertilizer would prove profitable.

THE AGENCY FIELD

The results secured on the Agency field on the Grundy silt loam in Wapello county are given in table XIV. In these results the yields on the check plots are the averages of the results secured on plots 1, 7 and 13. The beneficial effect of manure on this soil is quite definitely shown on the corn, oats, wheat, clover and timothy, the increase being very definite in all cases. Lime in addition to manure gave still further increases on the corn, wheat and clover but showed no effect on the oats. Rock phosphate proved of large value on all the crops grown, and acid phosphate likewise showed definite increases. In most cases the acid phosphate seemed to have a somewhat greater effect than the rock. Increases were secured with the use of the complete commercial fertilizer, but they were not quite as large in most instances as those secured when acid

TABLE XIV—FIELD EXPERIMENT. AGENCY FIELD
Grundy Silt Loam—Wapello County.

Plot No.	Treatment	Corn bu. per A. 1918	Oats bu. per A. 1919	Winter wheat bu. per A. 1920	Clover & timothy tons per A. 1921	Timothy tons per A. 1922
1	Check*	58.4	50.4	22.7	1.76	2.20
2	Manure	64.5	62.2	31.5	2.09	2.20
3	Manure+Lime	66.7	58.3	36.7	2.20	2.25
4	Manure+Lime+Rock phosphate	68.7	63.6	38.7	2.52	2.30
5	Manure+Lime+Acid phosphate	70.0	66.6	40.0	2.39	2.80
6	Manure+Lime+Complete commercial fertilizer	66.0	65.6	34.7	2.52	2.50
8	Crop residues	58.5	49.0	31.4	1.51	2.20
9	Crop Residues+Lime.	61.2	59.5	**	2.02	2.40
10	Crop Residues+Lime+Rock phosphate	61.7	61.2	36.4	2.33	2.65
11	Crop Residues+Lime+Acid phosphate	63.5	61.2	36.3	2.19	2.75
12	Crop Residues+Lime+Complete commercial fertilizer	62.5	52.0	35.6	2.17	2.65

*The check plots yields are the averages of the yields on Plots 1, 7 and 13. **Yield not secured.

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phosphate was applied. It seems that this material would be less desirable on this soil than a phosphorus fertilizer.

The crop residues had a slight effect during the last few years but in the first years of the experiment there was so little material applied that no effect could be expected. The addition of lime proved very desirable in all cases on the residue plots. Rock phosphate and acid phosphate both brought about distinct effects on the various crops grown, there being very little choice between the two materials. The complete commercial fertilizer seemed slightly less effective than the phosphorus carriers. The results secured on this field in Wapello county very largely confirm those secured on the Mt. Pleasant field in Henry county and show that on the Grundy silt loam, manure is a valuable fertilizing material, lime should be applied when needed and phosphorus fertilizers will probably prove of value. Just which material should be employed must be determined for individual farm conditions.

THE FARSON FIELD

The results obtained on the Farson field on the Grundy silt loam in Wapello county are given in table XV. The yields secured on the grain system plots are not included inasmuch as there has been little effect of treatment. It is evident from these results under the livestock system of farming, that manure is a valuable fertilizing material for use on this soil. Lime in addition to manure brought about increases which were particularly noticeable in the case of clover. Rock phosphate and acid phosphate both give distinct crop increases, the acid phosphate apparently being somewhat superior to the rock. The differences are not definite enough, however, to warrant the drawing of conclusions. The complete commercial fertilizer gave crop increases which in some cases were slightly larger than those produced by the phosphates. This was not true with all the crops, however, and in general the effects seemed to be very little different than those produced by the phosphates on the average. Apparently the use of a phosphate fertilizer on this soil would be more desirable than the application of a complete commercial fertilizer. Again these results confirm those secured on the same soil type in Henry county and on another field in Wapello county. They show

TABLE XV. FIELD EXPERIMENT. FARSON FIELD II.
Grundy Silt Loam—Wapello County

Plot No.	Treatment	Oats bu. per A. 1918	Wheat bu. per A. 1919	Clover ton per A. 1920	Corn bu. per A. 1921	Oats bu. per A. 1922
1	Check	72.2	11.7	1.23	69.8	27.2
2	Manure	72.2	11.7	1.19	80.4	....*
3	Manure+Lime	70.0	15.2	1.43	78.6	44.1
4	Manure+Lime+Rock phosphate	72.2	16.1	1.42	79.1	49.8
5	Manure+Lime+Acid phosphate	70.0	14.8	1.83	79.0	55.5
6	Manure+Lime+Complete commercial fertilizer	74.3	14.6	1.66	81.8	46.0

*Yield not secured.

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TABLE XVI. FIELD EXPERIMENT. HUDSON FIELD
Tama Silt Loam—Black Hawk County

Plot No.	Treatment	Corn bu. per A. 1918	Oats bu. per A. 1919	Corn bu. per A. 1920	Corn 1921	Oats bu. per A. 1922
1	Check	45.8	47.6	53.2	.....	44.8
2	Manure	49.3	54.7	62.8	no	53.1
3	Manure+Lime	54.4	59.2	67.4	crop	59.6
4	Manure+Lime+Rock phosphate	56.5	64.9	73.3	secured	58.1
5	Manure+Lime+Acid phosphate	57.4	62.2	73.3	.....	53.2
6	Manure+Lime+Complete commercial fertilizer	58.5	57.5	72.4	.....	62.2

the value of manure and lime, and indicate quite definitely that phosphorus fertilizers may prove distinctly profitable.

THE HUDSON FIELD

The results obtained on the Tama silt loam in Black Hawk county are given in table XVI. Again only the yields obtained under the livestock system are given as the crop residue plots are not yielding definite enough results. In 1921 the crop was not secured on these plots.

Manure brought about a distinct increase in the crop yields in all cases on this soil. Lime in addition to manure gave a further increase in the corn and oats. The application of rock phosphate and of acid phosphate showed still further increases in practically all cases. These two materials exerted very similar effects and a choice cannot be made as to which one should be employed on this soil until more complete data are secured. The complete commercial fertilizer gave distinct crop increases, but in most cases the effects were very little larger than those produced by the phosphates. In some instances the material seemed less effective. Apparently the phosphate fertilizers are more desirable for use on this soil than the complete brands. The results as a whole indicate clearly that manure is a very valuable fertilizer for application to the Tama silt loam. Lime should be applied when the soil is acid as is usually the case, and a phosphorus fertilizer would undoubtedly yield profitable returns. Whether rock phosphate or acid phosphate should be employed must be determined by tests under individual farm conditions.

AVERAGE RESULTS OF FIELD EXPERIMENTS ON THE TAMA SILT LOAM

The average results of all the field experiments on the Tama silt loam are given in table XVII. The check or untreated plot averages are calculated from the yields on the three check plots in each field, 1, 7 and 13, and averages are then struck from the check yields on all the fields. These results show rather interesting effects of fertilizer treatment on the soil and while the number of fields represented is not large, rather definite conclusions may be drawn from the results. The application of manure increased the yield of corn and oats on this type to a very definite extent. Lime in addition to manure gave further increases which were larger than might be expected on these crops inasmuch as this material usually exerts its largest effect on the legume crop of the rotation.

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The application of rock phosphate brought about a large additional effect on the two crops, the influence being particularly evident in the case of the corn altho the oats was increased to almost as large an extent. Acid phosphate proved of slightly more effect than the rock in the case of the oats, but had a smaller effect on the corn. The complete commercial fertilizer showed a distinct increase in both crops, the effect being more evident in the case of the oats. Crop residues increased the corn and oats to some extent, and the addition of lime brought about a still further increase which is particularly evident in the case of the oats. Rock phosphate and acid phosphate both gave considerable increases, the acid phosphate proving somewhat superior to the rock with both the corn and the oats. The complete commercial fertilizer showed less effect than the phosphates on the corn but a larger effect on the oats.

It is evident from these results that manure will yield profitable effects on the Tama silt loam and that lime should be used and will prove beneficial on the corn and small grain crops of the rotation as well as on the legume. Phosphorus fertilizers are of value on this type and just which phosphate fertilizer should be used must be determined under individual farm conditions. In some instances the rock phosphate seems somewhat preferable but in other cases acid phosphate is more profitable. The latter material generally shows better effects where manure is not available for use. The complete commercial fertilizer gives definite crop increases but these are not as profitable as those secured from the use of the phosphates because of the larger cost of the complete fertilizers.

AVERAGE RESULTS OF FIELD EXPERIMENTS ON THE GRUNDY SILT LOAM

The average results obtained from all the experiment fields on the Grundy silt loam are given in table XVIII. As in the preceding case, the check yields are the averages of the yields on the three check plots on each field averaged for all the fields represented. There is some definite evidence of the value of ap-

TABLE XVII. TAMA SILT LOAM

Average Crop Yields and Increases Due to Fertilizer Treatment
Iowa Experiment Fields

Treatment	Corn*		Oats*	
	Bu. per acre	Increase from treatment Bu. per acre	Bu. per acre	Increase from treatment bu. per acre
Check	63.3	.....	46.0	.....
Manure	69.6	6.3	49.4	3.4
Manure+Lime	71.8	8.5	56.3	10.3
Manue+Lime+Rock phosphate	77.7	14.4	58.6	12.6
Manue+Lime+Acid phosphate	75.3	12.0	56.7	10.7
Manure+Lime+Complete commercial fertilizer	73.7	10.4	62.9	16.9
Crop Residues	69.7	6.4	47.0	1.0
Crop Residues+Lime	71.8	8.5	57.9	11.9
Crop Residues+Lime+Rock phosphate	74.4	11.1	58.9	12.9
Crop Residues+Lime+Acid phosphate	75.7	12.4	63.3	17.3
Crop Residues+Lime+Complete commercial fertilizer	72.7	9.4	68.0	22.0

*The corn yields are the averages of 3 years results on 2 fields. The oats yields are the averages of 2 years results on 2 fields.

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TABLE XVIII. GRUNDY SILT LOAM

Average Crop Yields and Increases due to Fertilizer Treatment.
Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*		Winter wheat	
	Bu. per acre	Increase from treatment Bu. per acre	Bu. per acre	Increase from treatment Bu. per acre	Tons per acre	Increase from treatment Tons per acre	Bu. per acre	Increase from treatment Bu. per acre
Check	56.9	.....	45.6	.....	1.98	.....	22.4	.....
Manure	62.9	6.0	49.6	4.0	2.14	0.16	29.2	6.8
Manure+Lime	67.3	10.4	56.6	10.0	2.34	0.36	32.5	10.1
Manure+Lime+Rock phosphate	69.0	12.1	60.2	14.6	2.65	0.67	34.2	11.8
Manure+Lime+Acid phosphate	72.7	15.8	64.9	19.3	2.86	0.88	34.7	12.3
Manure+Lime+Complete commercial fertilizer	69.2	12.3	61.7	16.1	2.83	0.85	33.1	10.7
Crop residues	60.3	3.4	51.6	6.0	2.23	0.25	25.1	2.5
Crop residues+Lime	61.9	5.0	53.3	7.7	2.33	0.35	.....	.....
Crop residues+Lime+Rock phosphate	63.0	6.1	61.5	15.9	2.62	0.64	28.8	6.4
Crop residues+Lime+Acid phosphate	64.8	7.9	59.3	13.7	2.65	0.67	28.9	6.5
Crop residues+Lime+Complete commercial fertilizer	65.8	8.9	56.9	11.3	2.62	0.64	28.3	5.9

*Corn yields averaged from 11 years results on 9 fields; oats from 6 years results on 4 fields; clover from 10 years results on 8 fields; and wheat from 3 years results on 3 fields.

plications of various fertilizers indicated in these results, and inasmuch as a rather large number of fields are represented and a good many crops, the results may be considered quite conclusive. The application of manure to the Grundy silt loam proved distinctly profitable, increases being secured with all the crops. Lime in addition to manure was always desirable on this soil and gave profitable increases on all crops in the rotation. Its effect was not limited to the legume, but was evidenced on the corn and small grain crops of the rotation. Rock phosphate applied with manure and limestone gave increases in all cases and acid phosphate likewise proved of value on all the crops. The effects of acid phosphate on this type were considerably greater than the effect of the rock phosphate. The complete commercial fertilizer showed more effect than the rock phosphate, but did not prove as valuable as the acid phosphate when applied with manure and lime. The use of crop residues gave some effect on the crops grown and lime in addition proved of value just as was noted in the results obtained when it was used with manure. The rock phosphate increased crop yields but the acid phosphate gave larger effects in most instances. The complete commercial fertilizer gave increases which were very similar to those obtained with the acid phosphate.

These results as a whole show a very definite value from the application of manure to the Grundy silt loam. Lime is very necessary for the best legume growth and will prove of value on the other crops of the rotation. Phosphorus fertilizers show effects both with manure and with crop residues, the increase being the greater where the manure is applied. Acid phosphate seems to be somewhat more effective than the rock, but the results are very similar with the

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two materials and hence farmers should test the two phosphates and determine for their own conditions which one should be used. The complete commercial fertilizer showed increases which were very similar to those produced by the phosphates therefore this material cannot be considered as desirable as the phosphates. It is interesting to note that the average results on the Grundy silt loam as given in the above table and also the results on the Tama silt loam in table XVII bear out very definitely the indications shown in the individual field experiments discussed earlier. Apparently on these two soil types at least there is very definite evidence of the value of manure, lime and phosphorus.

THE NEEDS OF MAHASKA COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The general treatments recommended for the soils of this county are based upon the laboratory, greenhouse and field experiments discussed in the previous pages. While the field experiments are under way in other counties, the soil types on which they are located are representatives of some of the main types in Mahaska county and the results may be considered quite definitely indicative of the effects which may be secured in this county from the use of the same fertilizing materials. The recommendations are also based upon the general experience of farmers and the suggestions made have been proven valuable by considerable practical experience. The data from the field experiment in this county will be available after several years results have been secured, but there is sufficient evidence at present from the individual fields referred to and from the average field experimental results discussed, to show rather definitely the principal needs of the soils of Mahaska county.

Farmers should appreciate the fact that the suggestions made may all be put into effect on the farm and that the tests suggested are simple and may be easily carried out. Many farmers are conducting fertility tests on their own farms and are securing results of large value to themselves and of considerable interest to others located on the same soils. The Soils Section of the Iowa Agricultural Experiment Station is ready to aid farmers who wish to carry out tests on their soils. It will be much more satisfactory in the long run for the farmers to test out the value of such materials as phosphorus fertilizers by making applications to small areas, and then if profitable returns are secured, applications may be made to extensive areas with the assurance of profit.

LIMING

The soils of Mahaska county have all been shown to be acid in reaction and hence the need of lime on the soils of this county is quite evident, and in general there seems to be indicated in the tables a rather large demand for lime. The upland soils are apparently quite strongly acid. In a few instances there is a small lime content in the lower soil layers, and the samples do not react acid, but in no case is there any considerable amount of lime present, hence these soils

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will all need to be limed in the very near future or they will become distinctly acid. Soils which are under cultivation and are intensively cropped tend to lose their lime content rather rapidly because of utilization by crops, losses by leaching and also because of the production in the soil of acids with which the lime reacts. As acidity increases in the soil with the disappearance of lime, the fertility becomes lower and it becomes increasingly difficult to secure satisfactory crop growth, particularly in the case of legumes. Red clover and alfalfa are very sensitive to acidity and if satisfactory production of these crops is to be secured, lime must be used on an acid soil.

The application of lime to soils is valuable from the fertility standpoint because it improves the physical conditions, the chemical conditions, and the bacteriological conditions in the soil. It opens up heavy clay soils making them better aerated and it tightens up light sandy soils, making them more retentive of moisture and plant food and less subject to injury by drought. Lime improves the soil chemically because it neutralizes the acids which are produced from the decomposition of organic matter in the soil. If these acids are allowed to accumulate they often bring about injurious effects. It also supplies the necessary plant food calcium and with many crops this may be of large value. It improves soils bacteriologically because desirable soil bacteria will not act properly unless the soil is well limed. Decomposition processes will not proceed properly, nitrate production will not occur, nitrogen fixation will be restricted and in general the production of available plant food will be limited so that crops may suffer. In some cases the application of lime may increase crop yields because of improved physical conditions of the soil, because of the chemical effect or because of better conditions for bacterial growth. In general, however, it seems probable that the beneficial effect of lime is due to the influence on all these conditions together.

The amount of lime which should be applied to soils will vary with the individual soil conditions. Figures given earlier in this report indicate the needs merely of the samples tested and should not be taken to show the general needs of the soil types. Soils vary widely in lime requirement, even within types and hence tests should always be made on every field before lime is used. In this way it is possible to supply sufficient lime and to avoid too small an application, both of which are undesirable economically. Farmers may test their own soils for lime needs but it will probably be more satisfactory if they will send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

The farmers of Mahaska county should see to it that their soils are tested and that lime is applied as needed if they are to secure the best crop growth. Furthermore, it should not be concluded that one application of lime will be sufficient for all time. Tests should be made at regular intervals at least once in a four year rotation to insure the maintenance of a proper amount of lime in the soil. The tests should be made preferably preceding the growing of the legume crop of the rotation and the lime may then be applied where it is most needed, that is for the legume. Other soil treatments are less valuable and frequently show no effects whatever on an acid soil, hence the use of lime should be con-

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sidered as a fundamental soil treatment. Further information regarding the loss of lime from soil, the need of lime by certain crops and other points in connection with liming, are given in Bulletin 151 and Extension Circular 105 of the Iowa Agricultural Experiment Station.

MANURING

The soils of Mahaska county are quite generally low in organic matter and while not strikingly deficient, there is evidence of a need for fertilizing materials to build up and maintain the organic matter supply. The application of manure is particularly desirable on all the soils of the county as is evidenced by the beneficial effects secured from the use of this material indicated in the greenhouse and field experiments discussed earlier in this report. The practical experience of many farmers confirms the results indicated above in showing the large fertilizing value of manure on the various soils of the county. No other fertilizer proves as profitable as does manure and in fact other fertilizing materials quite generally give smaller effects when applied to soils in the absence of manure. Wherever manure is produced on the farm and is available for utilization, it should be considered a fundamental fertilizer treatment for the soils. Manure exerts a beneficial effect on the soils of Mahaska county even where there is apparently a sufficient supply of organic matter present, and in fact the results are often more striking in such cases than on soils which are lighter in color and apparently poorer in organic matter.

Manure is of value on soils because of its influence on the physical, chemical and bacteriological conditions in the soil. Heavy, impervious soils are opened up, made less retentive of moisture and better aerated. Light open soils are made more retentive of moisture, less open and porous and less apt to lose valuable plant food constituents by leaching. Manure supplies actual plant food to the soil and hence it has a chemical effect. It contains a large portion of the plant food contained in the feed of the animals, and serves, therefore, to return to the soil much of the fertility removed by the crops grown and used as feed. It serves to prolong the life of the soil by increasing the period of time which must elapse before any one of the essential elements will become deficient. Manure supplies a large amount of organic matter to soils and this has a chemical effect on the soil and also a physical and bacterial effect.

Enormous numbers of bacteria are contained in manure and these organisms are responsible for the production of available plant food. The organic matter supplied with the bacteria furnishes them with food material, hence there is a stimulation in all forms of desirable bacterial action, and soil conditions for the best crop growth are much improved. In many cases the application of manure may prove of value largely because of the stimulation of bacterial action and better production of available plant food. On soils apparently well supplied with organic matter and not strikingly low in plant food constituents, the bacterial effects of manure are undoubtedly of most importance. In general crop increases secured from the use of manure may be attributed to a combination of bacterial, chemical and physical effects.

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Manure is a waste product on the farm and too often it is improperly stored and handled so that it undergoes large losses before being applied to the soil. The value of these losses is quite commonly overlooked. Experiments have shown that when stored in uncovered heaps exposed to the weather and the liquid portion allowed to wash away, manure may lose as much as 90 per cent of the valuable constituents present. When such losses are permitted actual money loss occurs because of the fact that the effect of the manure on crop growth is correspondingly reduced. Crop increases are much less from the application of improperly stored manure, and the difference in effect from well handled manure brings a difference in actual income on the farm. If carefully stored and applied, manure may return to the soil 75 to 80 percent of the plant food removed in the crops grown. It is very necessary that precautions be taken on the farm to prevent losses from manure. It may be stored in a covered yard or pit or in some other manner. No one method of storing can be recommended for all conditions but in general it may be said that any method which will keep the manure moist and compact and protected from the weather will prove satisfactory. Farmers may be assured that any small expense involved in properly storing manure will be well warranted by the increased crop returns secured from its use.

Usually 8 to 10 tons of manure is applied per acre once in a four year rotation. In general no larger application than this is possible on the average farm because of insufficient production of manure. In some cases larger amounts of manure might be used with profit but if large applications are made to one field some other portion of the farm will usually be left without treatment. The average application mentioned may be considered about the maximum on any farm where care is taken to apply manure to all the soils. There is little danger of putting on too much manure, but it may be mentioned that it is rarely advisable to apply more than 16 to 20 tons for ordinary farm crops. In garden or truck farming, larger applications may often be made with profit.

In grain farming no manure is available for application to the soil and hence some other material must be employed to keep up the organic matter supply. On the livestock farm the amount of manure produced is often insufficient to meet the soil needs and some material must be used to supplement the manure. In both cases green manuring may be practiced to advantage. Legumes are most profitable for use as green manures because they have the ability when well inoculated to draw upon the nitrogen content of the atmosphere and thus they act as a nitrogenous fertilizer as well as a source of organic matter, having a double value on the soil. Non-legumes may be employed in some instances where the nitrogen factor is not so important but in general if organic matter is needed, nitrogen is also low and legumes should be employed. Many legumes are available for use as green manures. Some one may be chosen which will fit in with almost any farming and cropping system and under the particular soil and climatic conditions. In many cases in Mahaska county, green manuring would undoubtedly prove of value from the standpoint of increasing crop yields and making the soils more productive. The practice should not be followed carelessly, however, nor blindly, as it may prove quite undesirable if conditions are

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not satisfactory. Thus, if the soil is too dry the green material may not decompose rapidly enough and there may be some injury to the moisture condition in the soil. Suggestions regarding green manuring, under special conditions will be given by the Soils Section upon request. Frequently the second crop of clover is turned under in the soil and this serves as a partial green manuring crop. The clover seed may be removed and the remainder of the crop turned under with good effect on the soil. In some instances a legume may be seeded in the corn at the last cultivation and turned under to improve the fertility condition of the soil.

Organic matter may be applied to the soil by a proper utilization of all crop residues such as straw and stover. Frequently these materials are burned or otherwise destroyed and their value is lost. They contain considerable amounts of fertility constituents as well as organic matter, and hence they have a double value on the soil. They may be utilized for feed or bedding and returned to the soil mixed with the manure, as is the common practice on the livestock farm. On the grain farm they may be stored and allowed to decompose partially before application, but under both systems of farming the proper utilization of the crop residues is very important from the standpoint of keeping up the organic matter supply. When crop residues are properly used, farm manure is applied without having suffered losses of valuable constituents, and leguminous crops are utilized as green manures, the organic matter content of soils may be kept up and large yields of crops insured.

THE USE OF COMMERCIAL FERTILIZERS

Many of the soils in Mahaska county are rather poorly supplied with phosphorus, and it would seem that phosphorus fertilizers would probably be of value in many cases at the present time. They will certainly be needed on these soils in the near future if satisfactory crop yields are to be secured. The greenhouse experiments and field tests referred to earlier in this report give rather definite indications of value from the use of phosphorus fertilizers on some of the more extensive types in the county. It would seem, therefore, that many farmers in the county would find it profitable to test the application of a phosphorus fertilizer to a small area. They could then determine the desirability of applying the same material to a large area.

The total phosphorus content of soils indicates merely the store of phosphorus, and does not necessarily show how much of the element will be provided in an available form for plant use. A low content of phosphorus indicates quite definitely that there will not be a sufficient production of available phosphorus.

When the total supply in the soil decreases, the amount made available decreases much more rapidly, hence a low content of total phosphorus shows rather definitely a need for phosphorus fertilization. Even where the total supply is not low, however, available phosphorus fertilizers may prove profitable if the element is not being changed into a soluble form sufficiently rapidly to keep crops supplied. Even on those soils in Mahaska county where the supply of phosphorus is not extremely low, therefore, applications of a phosphorus fertilizer might be very desirable.

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Two phosphorus fertilizers, rock phosphate and acid phosphate, are available for use agriculturally. Rock phosphate is slowly available in soils and rather large applications must be made to secure beneficial effects. Acid phosphate contains the element in an available form and it is more expensive, but smaller applications may be used with desirable effects. The field tests which are now under way in the county, include the use of both these materials. The experiments in other counties described in this report likewise include both fertilizers. Evidence is not yet sufficient, however, for a choice to be made between them for use on the soils of Mahaska county. Comparative results from the two materials must be secured for several years and with different crops before definite conclusions can be drawn. It would seem that for the present farmers should test both of these materials on their own soils and thus they may readily determine for their own conditions which fertilizer will give the most profitable returns. Accurate comparisons of value will depend upon the actual crop increases secured and a calculation of the value of these increases over against the cost of the treatments. It is comparatively a simple matter to test the use of these phosphorus fertilizers on the farm and if definite results are secured on small areas then the farmer may apply the particular material which gives the best results to a large area with the assurance of profit. Directions for carrying out such field tests on the farm are given in Circular 82 of the Iowa Agricultural Experiment Station and the farmers of Mahaska county are urged to aid in the general solution of the phosphorus problem by determining the needs of their own soil by the aid of these simple field tests.

The soils of the county are not strikingly deficient in nitrogen but the amount present is insufficient to provide for continued production of satisfactory crops over any number of years. Under cultivated conditions where crops are removed and the soil is well drained, nitrogen is constantly taken out of soils, and the supply gradually decreases. It is quite essential that some means be employed to maintain the supply of this element in the soil. In several of the types the addition of nitrogenous fertilizers might prove profitable at the present time, particularly if natural materials such as farm manures or leguminous green manures are employed. These two materials are the most commonly utilized nitrogenous fertilizers, and they are most desirable for general farming purposes.

On the livestock farm the careful storage and return of manure to the land will go far toward keeping up the nitrogen supply. On the grain farm leguminous green manure crops must be utilized in place of manure. Where the supply of manure is insufficient, green manuring should be practiced also. Every rotation should contain a legume, and if the legume is well inoculated and all or part of the crop turned under in the soil, considerable nitrogen may be added. If the legume is removed from the land there will be no increase in nitrogen, and if it is not inoculated the crop will not act in any way as a nitrogenous fertilizer. It is important, therefore, to insure thoro inoculation of the legume and to plan on at least a partial return of the green material of the crop if the nitrogen supply of the soil is to be increased. Frequently only the seed of the legume is removed and the remainder of the crop is plowed under. This is a very desirable method of handling the legume crop. Occasionally legumes may

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be used as catch crops, and in this way the entire crop is utilized for increasing the nitrogen and organic matter content of the soil.

Crop residues when turned under in the soil constitute a means of returning to the land a portion of the nitrogen removed, and it is very important that they be properly utilized if the nitrogen supply is to be maintained. These materials along with farm manures and green manures are the natural fertilizers available for maintaining the nitrogen supply in the soil, and they may also be utilized to increase the supply of this element and the organic matter content.

Commercial nitrogenous fertilizers may be utilized in small amounts as top-dressings to stimulate the early growth of crops, but their use for general farm crops on the soils of this county cannot be recommended at the present time. If tests on small areas prove them to be of value they may be utilized, but generally leguminous green manures are much cheaper and quite as satisfactory for keeping up the nitrogen in soils.

Analyses of many of the soils of the state made earlier showed a large content of potassium in practically all of them. It seems hardly likely, therefore, that potassium fertilizers would prove profitable on general farm crops. Only where the production of available potassium is insufficient would it be desirable to add a small amount of a commercial potassium fertilizer. Small applications of the muriate or sulphate of potassium might be quite desirable as top-dressings to stimulate the early growth of some crops but these materials should not be applied generally until the value has been shown by tests. If the soil is kept in the best physical condition, well supplied with organic matter, and properly drained and aerated, there should be a sufficient production of potassium in an available form to supply crop needs for many years. Some of the field tests now under way in the state include a potassium fertilizer and hence results are being secured which may later indicate whether or not these materials may be profitably employed. For the present it can merely be recommended that farmers who are interested test the application of a potassium carrier to a small area before they make any extensive applications.

Complete commercial fertilizers are not recommended at the present time for general use in this county for the reason that experimental evidence at hand on the field tests indicate that the phosphorus fertilizers are more profitable. The complete brands are more expensive than the phosphorus carriers and must bring about much larger crop increases if they are to prove profitable. The results given earlier in this report show very little value from the complete brands over the acid phosphate and hence it would seem that the nitrogen and potassium carried in the complete fertilizer has little effect on the soil. Even if nitrogen in nitrate of soda and potassium in muriate of potash give some effects as top-dressings, the complete brands would not necessarily prove as desirable as the use of the individual fertilizers owing to the fact that the nitrogen is not necessarily in the same form. Results are being secured continually with complete fertilizers and the data are proving quite definite.

Farmers may test the use of any complete brand of fertilizer on their own soils and if profitable returns are secured they may apply the material to a larger area with the assurance of profit. Such materials should be tested in com-

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parison with a phosphorus carrier, however, if definite conclusions are to be drawn as to the relative value of the complete fertilizers. There is no objection to the use of complete commercial fertilizers and in fact in many cases where truck farming is practiced, such materials can be applied very profitably. For general farming on the main soil types of Mahaska county it seems that phosphorus fertilizers are of more value.

DRAINAGE

The soils of Mahaska county as a whole are quite adequately drained. The map given early in this report indicates the extent of the natural drainage system and shows that artificial drainage is needed only in a few instances. There are a few areas, small in extent, in the Grundy silt loam on the level uplands where tiling would be of value. The Grundy silty clay loam is quite generally in need of artificial drainage. The Putnam silt loam on the upland sometimes is in need of tiling. On the terraces the Bremer silty clay loam and the Calhoun silt loam are frequently too wet and occasionally the Bremer silt loam will be improved by tiling. Several of the Wabash soils on the bottoms need drainage but these types also need protection from overflow if the soils are to be made properly productive.

Wherever soils are too wet, tiling is very necessary and in fact should be the first treatment to make the soils properly productive. It should be emphasized that the installation of tile is a paying proposition when judged from the standpoint of the value of the increase in crops secured and the farmers in Mahaska county may be certain that tiling out wet land will prove profitable to them.

THE ROTATION OF CROPS

The proper rotation of crops is necessary on all soils if satisfactory yields are to be secured from year to year. The continuous growing of any one crop reduces the fertility of the soil very rapidly due to undesirable conditions which result in the soil. Even if the crop grown is a money crop, and of more value than the other crops in the rotation, the total income from the land over a period of years will prove greater where a rotation is practiced. The yields of crops are so reduced under continuous cropping that frequently their growth becomes unprofitable and the farmers are forced to adopt a rotation. Conditions should not be allowed to reach such an extreme state, however, and too much emphasis cannot be placed on the importance of following a proper rotation on every farm.

No one rotation can be recommended for use under all conditions. Several satisfactory rotations are in use thruout the state and a few of these which are suitable to conditions in Mahaska county are suggested in this report. It should be noted that these rotations may be modified as desired to fit in with local conditions. In fact almost any rotation will prove desirable provided a legume is included and the money crop. The following rotations are suggested for use in this county.

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I. FOUR OR FIVE-YEAR ROTATION

First year:	Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.
Second year:	Corn.
Third year:	Oats (with clover or with clover and timothy.)
Fourth year:	Clover. (If timothy was seeded with the clover, the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy.)

II. FOUR-YEAR ROTATION WITH ALFALFA

First year:	Corn.
Second year:	Oats.
Third year:	Clover:
Fourth year:	Wheat.
Fifth year:	Alfalfa. (This crop may remain on the land five years. This field should then be used for the four-year rotation outlined above.)

III. THREE-YEAR ROTATION

First year:	Corn.
Second year:	Oats or wheat (with clover seeded in the grain.)
Third year:	Clover. (Only the grain and clover seed should be sold; in grain farming most of the crop residues, such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil.)

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of the land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles to

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gether and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gulling. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of the fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

Erosion occurs to an injurious extent in several of the soils in Mahaska county. The Clinton silt loam is badly washed in many areas, particularly in the more rolling locations. The Lindley silt loam of the upland is also very frequently injured considerably by the washing action of water. In fact, in many cases most of the surface soil of the Lindley has been washed away. There has been some injurious erosion in the case of the Jackson silt loam on the terraces, but the effect of washing is not extensive on the second bottom soils. It is important to consider briefly the causes of erosion and the methods which may be employed to prevent or control washing inasmuch as these methods should frequently be utilized to prevent serious injury to the Clinton silt loam, the most extensive upland type.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows" to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle with it, frequently result in the formation of gullies.

"Plowing in."—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In."—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three or four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

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Earth Dams.—Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways, but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls.—The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch, but it does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

"Staking in."—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of the dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brush-piles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of "staking in" which is being used with success in some sections, consists in covering the bottom and side of the ditch with straw for a distance of four to ten feet, depending upon the width of the ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the

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point down stream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey"' dam.

The "Christopher" or "Dickey" Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T", called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam.—This dam is practically the same as the Christopher or Dickey Dam. In fact the principle of construction is identical. In some sections the name "Adams Dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Christopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam.—Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making

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such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam.—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam.—The use of woven-wire, especially in connection with brush or rubbish, has sometimes proven satisfactory for the prevention of erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips.—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain areas and it might be employed to advantage in many other cases.

The Concrete Dam.—One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design, such dams cannot be considered as adapted to general use on the farm.

Drainage.—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gul-

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lies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies, and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such lowlying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling.—The straightening of the larger streams in bottomland may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottom land, and it often proves very efficient.

Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter.—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw and corn stalks may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion.

Growing Crops.—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and red top are also quite desirable for use in such locations. The root system of such crops as these holds the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing.—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called "contour discing" and it has proven quite satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the

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spring, preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Sod Strips.—The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing.—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

DESCRIPTION OF INDIVIDUAL SOIL TYPES IN COUNTY*

DRIFT SOILS

There is one drift soil in the county which is classified as the Lindley silt loam. It is of minor importance, covering 4.0 percent of the total area.

LINDLEY SILT LOAM (32)

The Lindley silt loam occurs in all parts of the county in narrow areas occupying generally the slopes to the stream courses. It occurs in association with the Clinton silt loam and the Union silt loam, frequently separating the Clinton silt loam from the bottomlands. The larger areas occur along Black Oak, Muchakinock and St. Joseph creeks and tributaries of the North and South Skunk rivers.

The Lindley silt loam is a light yellowish-brown or brown silt loam grading at 8 to 10 inches into a yellowish-brown gritty silty clay loam. At 18 to 20 inches it passes into a brown, stiff clay mottled with drab. The subsoil contains a large percentage of sand, gravel and small stones. In some areas the type approaches a loam in texture, especially where it occurs on the steeper hillsides and eroded slopes. Frequently the soil in these locations is darker in color than the typical. The surface soil is probably of loessial origin, the underlying drift of Kansan origin approaching close to the surface because of the washing away of the loessial covering. The drainage of the type is quite adequate. It is subject to erosion and unless properly handled and protected from washing, may be very seriously washed.

Only a few areas of the type have been cleared and brought under cultivation. The native forest growth includes white oak, hickory, ash, hazel, and elm. Where cultivated, corn and oats are grown, but the yields are not very satisfactory, be-

*The descriptions given in this section of the report very closely follow those given in the Bureau of Soils report.

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ing usually lower than on the other upland types. Because of its very rough topography and tendency to erode, most of the type should probably be kept in bluegrass and used for pasture. Comparatively little of it is used for cultivated crops. It is very low in organic matter and if cultivated should receive liberal applications of farm manure or green manure crops. It is acid and in need of lime and it would undoubtedly respond to applications of phosphorus fertilizers. It should be protected from erosion whenever cultivated and some of the methods suggested in an early section of this report may be utilized to prevent the formation of gullies and the even more serious sheet washing. The value of the type is greatest from the pasture standpoint.

LOESS SOILS

There are six loess types in the county, classified in the Clinton, Tama, Grundy, Knox, and Putnam series. Together they cover over three-fourths of the county, 76.9 percent.

CLINTON SILT LOAM (80)

The Clinton silt loam is the largest individual soil type in the county as well as the largest loess soil. It covers 33.4 percent of the total area. It is widely distributed thruout the county, occurring in irregular belts along both sides of the North and South Skunk rivers and the Des Moines river. The most extensive areas occur in the southwestern part of the county in association with the Tama silt loam. The type occurs in general between the more level to gently rolling uplands of the Tama and Grundy series and the rough areas of the Lindley which adjoins the bottomlands. The individual areas are very largely cut by the streams and bottomlands. In many instances the Clinton silt loam separates the broad upland areas from the bottoms without the occurrence of any intervening types, while in other cases, there are small areas of terrace soils particularly along the Des Moines and Skunk rivers. Much of the type is rough and broken in topography, particularly near the streams on steep slopes, in ravines and on narrow ridges. A portion of the type might have been separated as a broken phase as was the case in Wapello county, but the distinction was rather difficult in this county and hence no phase was separated.

The Clinton silt loam consists of 8 to 12 inches of a light brown to buff colored smooth silt loam. When dry the surface soil is often a light gray and may resemble the Marion silt loam. In wooded areas the surface material is somewhat dark colored, due to accumulations of organic matter. The subsurface soil is a more compact brown silt loam to light silty clay loam. At lower depths the subsoil becomes a distinct silty clay loam to clay varying in color from yellow to brown, usually mottled with gray. The type is so closely associated with the Grundy Tama, and Putnam silt loams that in many instances it is very difficult to draw exact boundaries between the soils. Small areas of the Marion silt loam occur in this county but their total acreage is so small that they have been included with the Clinton silt loam. The Marion silt loam is a light, ashy gray soil with a heavy, compact, very impervious subsoil. Three areas occur in the county, one two miles northeast of Bellefontaine; a second, one mile southwest of Givin and a third about three miles south of Tioga in White Oak township.

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In topography the Clinton silt loam is extremely variable, some having a rather rough to broken surface while other areas are almost level. The average topography is gently rolling to rolling except where the topography is level and here artificial drainage is usually needed. The heavy subsoil occurring in these flat areas is quite impervious and the difficulty in handling these areas of the type has led to their being called "hard-pan". Drainage is the chief treatment needed by these areas to make them readily cultivable.

The type was originally forested with oak, hickory, hazel, wild cherry and other trees. About 35 per cent of it is still in pasture and forest and much of this portion of the soil should probably not be cultivated. The areas which are at present under cultivation seem to be fairly productive when conditions are favorable. The area under cultivation is increasing as each year additional areas of the type are being cleared. In the cultivated areas the chief crops grown are corn, oats, wheat, clover, and timothy. Corn yields 20 to 75 bushels per acre, oats 20 to 60 bushels, wheat 10 to 35 bushels, and clover from 1 to 1½ tons of hay per acre. The type is well adapted also to the growing of apples, pears, cherries, small fruits and berries. It is readily cultivated except in the rough areas and in general is handled under the livestock farming system.

Crop yields are very much increased on this soil by proper methods of fertilization. It is low in organic matter and will respond to applications of farm manures. It is rather low in nitrogen and leguminous green manures will serve to supply this constituent. It is acid in reaction and should be limed if the best growth of legumes is to be secured. It is not well supplied with phosphorus, and phosphorus fertilizers will probably prove profitable on the soil in many cases at the present time. Experiments which have been carried out on this type indicate a profit from the use of phosphorus. Farmers are urged to test the value of rock phosphate and acid phosphate on this soil. The soil is apt to wash badly and may be seriously injured thru the formation of gullies. From among the suggestions made earlier in this report, some method may be chosen to prevent the growth of gullies and the washing away of the surface soil. The steeper slopes should undoubtedly be kept in sod as much as possible and many cultivated fields should be protected by the use of cover crops during the winter. Deeper plowing and the addition of organic matter would aid materially in cutting down the injurious effects of washing. The drainage of the type is usually adequate, frequently excessive. In a few instances tile drainage would be of value.

TAMA SILT LOAM (120)

The Tama silt loam is the second largest type in the county covering 22.4 per cent of the total area. It occurs in practically all parts of the county, occupying usually the gently rolling upland area which separates the level Grundy on the divides from the more strongly rolling to broken Clinton on the slopes to the streams. There are many rather extensive individual areas, but in general the type is found in comparatively narrow strips separating the Grundy from the Clinton as is characteristic in the northern part of the county or joining the Clinton as is characteristic of the areas in the southern part of the county.

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Fig. 8—Gently rolling slopes of Tama silt loam sometimes erode.

The surface soil of the Tama silt loam is a dark brown to black friable silt loam 10 to 12 inches in depth. It is usually dark brown when dry and black when wet. It grades gradually into a lighter brown silty clay loam, friable and crumbly when not too wet. In topography it is undulating to rolling. It is entirely derived from loessial material and is free from stones and boulders. The type is well drained and rarely is there any need for artificial drainage.

Practically all of the Tama silt loam is under cultivation, general farm crops being grown. Corn yields about 50 bushels per acre, oats 50 to 75 bushels per acre. Good yields of clover and timothy are secured in favorable seasons. The yields of these crops and other general farm crops grown are very satisfactory.

This type is a relatively fertile one and crop yields are quite generally good. It will respond, however, to fertilizer treatments. It seems to be fairly well supplied with organic matter but applications of farm manure prove of large value and bring about very profitable crop increases. It is acid in reaction and applications of lime are very necessary if satisfactory legume growth is to be secured. The phosphorus content of the soil is not high and phosphorus fertilizers seem to prove of value in many cases. It is probable that acid phosphate or rock phosphate could be used with profit on many of the Tama areas. Just which material should be employed can only be determined by tests on individual farms. Farmers may test the value of these materials by applications to small areas and thus determine the desirability of their more extensive use.

GRUNDY SILT LOAM (64)

The Grundy silt loam is the third largest soil type in the county, covering 20.3 percent of the total area. It occurs most extensively in the southeastern part, altho there are considerable areas of the type in the northern, eastern, and central portions. Only small areas occur south of the Des Moines river. The major

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portion of Cedar township and a large part of Harrison and Spring Creek townships are covered by this type. It is found on the broad, level divides between the streams and on the gentle slopes. It is usually separated from the rougher areas adjacent to the streams by areas of the more rolling Tama which in turn are separated from the streams by the strongly rolling areas of Clinton and Lindley.

The surface soil of the Grundy silt loam is a dark brown to black mellow silt loam 8 to 12 inches in depth. It grades gradually into a moderately friable brown to dark brown, light silty clay loam. At 18 inches it becomes a dark drab, yellowish-brown to dark brown, heavy, tenacious silty clay, mottled dark drab and yellowish brown. The yellow mottlings become more pronounced at the lower depths. Iron concretions occur in the lower subsoil. In some areas the subsurface layer is somewhat mottled and may be slightly gray in color, giving the type some of the characteristics of the Putnam soils. Occasionally the lower subsoil is so noticeably heavy and tenacious that it is locally called "hard pan." It is frequently quite difficult to draw an accurate boundary between Grundy silt loam and the Tama, as these types gradually change from one to the other. Topographic differences are usually evident, but in some instances do not serve as a distinct characteristic. Small areas of the Grundy silty clay loam too small to show on the map are included with the silt loam.

In topography the Grundy silt loam is level to gently rolling but drainage is ordinarily fairly well established. On a few of the more level areas, the installation of tile would be of material value in removing excess moisture. Most of the type is under cultivation or in pasture. It was never forested and native vegetation consisted of grasses. It is utilized for the growth of general farm

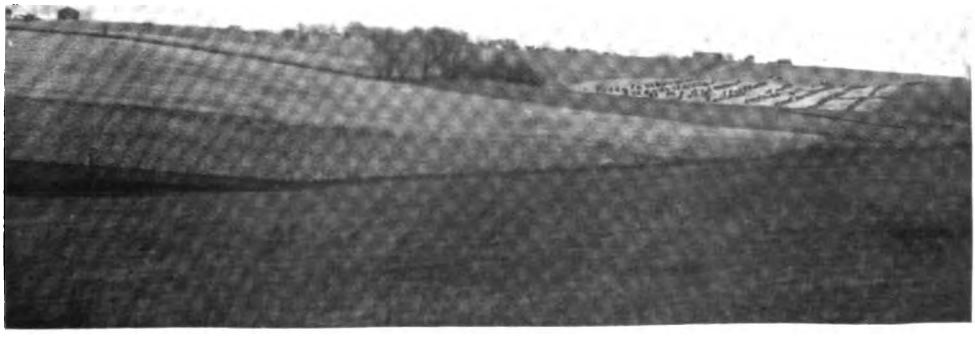

Fig. 9—Tama silt loam in Mahaska county.

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Fig. 10—Rolling Tama silt loam in bluegrass pasture.

crops, corn being grown the most extensively. Other crops include oats, hay, wheat, rye, buckwheat and barley. Yields of corn range from 35 to 100 bushels per acre, averaging about 45 bushels. Oats yield 25 to 65 bushels per acre, wheat 12 to 40 bushels, and timothy and clover, from 1 to 3 tons of hay per acre.

Crop yields on this type are quite generally satisfactory but larger crops may be secured when the soil is properly handled. Practically all of it is suitable for cultivation and may be utilized for the growth of general farm crops. In a few instances drainage is very desirable and the installation of tile would prove of large value. Applications of farm manure yield large effects on this soil and prove distinctly profitable. The type is acid in reaction and should be limed for the best growth of legumes. It is very desirable that a good crop rotation be practiced which should include a legume. By the proper growing of legumes the nitrogen content and organic matter content of the soil may be maintained. These materials are often of large value in addition to the use of farm manure. Phosphorus fertilizers often give profitable crop increases and the tests given earlier in this report indicate considerable value from the application of rock phosphate or acid phosphate. Farmers are urged to test the relative value of these two materials on their own soils and thus determine which can be used the most profitably.

KNOX FINE SAND (33)

The Knox fine sand is a minor loess type in the county, covering 0.3 percent of the total area. It occurs in several small areas in the county, the largest of which is just north of Eddyville along the Des Moines river. This area is about one square mile in extent. Other small areas occur northeast of Eddyville and 4½ miles north of Oskaloosa. Still smaller areas are found south of Peoria and west and south of Indianapolis.

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The surface soil of the Knox fine sand is a loose incoherent fine to medium sand, gray to grayish-brown in color, usually changing very little to a depth of 3 feet. In some places the subsoil ranges from a light brown to orange or yellow in color. The surface topography varies from undulating to dune-like and drainage is well established.

The type is relatively unimportant agriculturally, only about three-fourths being under cultivation. The remaining portion is occupied by a sparse growth of wild plum, scrub oak, shrubs, grass and sand burs. On the cultivated portions the most important crops grown are melons, small fruits and truck crops with some hay and corn. This type is best adapted for the growing of truck crops and to be made productive should receive liberal applications of farm manure and would be benefited by the turning under of leguminous green manures. It is low in plant food and should receive applications of fertilizing materials especially designed for truck crop growing on sandy soil. Complete fertilizer brands will prove profitable when used on this soil for truck crops. There are several brands on the market that may be used and it should be kept in mind that the soil is low in nitrogen, phosphorus and potassium and fertilization should include an application of these elements. The type is acid in reaction and should be limed, especially for the growth of legumes.

GRUNDY SILTY CLAY LOAM (115)

The Grundy silty clay loam is a minor type in the county, covering 0.3 percent of the total area. It occurs in several small areas in association with the Grundy silt loam on the uplands. It occurs chiefly in the southeastern part of the county the largest area being developed in the vicinity of Wright. Smaller areas are scattered over the upland south of Wright in Harrison and Cedar townships. There are a few small areas in other parts of the county.

The surface soil of the Grundy silty clay loam is a black, friable, silty clay loam 6 to 10 inches in depth, grading into a heavy compact plastic tenacious clay which breaks down into small cubes when dry. At 18 to 20 inches it passes into a bluish or yellowish-gray clay mottled with yellow and brown, the mottlings increasing with depth. Below 30 inches the clay subsoil is slightly less compact. In topography the type is flat to depressed and this, together with the compact subsoil renders drainage quite inadequate.

All of the soil is under cultivation, corn being the principal crop grown, followed by oats, wheat, grasses and clover. It is highly productive and the yields of all these crops are quite satisfactory. When well drained the yields are even higher than on the adjoining silt loam. The Grundy silty clay loam is chiefly in need of drainage to make it more productive and it should be handled with care in cultivation. It should not be plowed when too wet or too dry, as it is difficult to secure a uniform seed bed. Altho high in organic matter, the type will respond to small applications of farm manure but this material should not be applied preceding the small grain crop owing to the danger of lodging. The type is acid in reaction and should be limed, especially for the growth of legumes. Phosphorus fertilizers will also be needed in the future.

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PUTNAM SILT LOAM (66)

The Putnam silt loam is a very minor type in the county, covering but 0.2 percent of the total area. It is found in five areas, four of them in West Des Moines township south of Lakonta. The largest area is just south of this town with two small areas to the east. The two remaining areas are on the Monroe county line, one in Jefferson township and one extending over the boundary between Jefferson and West Des Moines township.

The surface soil of the Putnam silt loam is a dark gray silt loam 8 to 10 inches in depth. The soil appears almost black in color when wet. The subsurface soil consists of a distinct layer of ashy gray to white silt 6 to 8 inches in thickness. Below this the subsoil is a heavy silty clay loam to clay, mottled gray, brown and yellow. In flat, poorly drained areas, the soil is a light gray in color, while in other areas which are better drained it is dark brown to black. In topography the type is level and drainage is poor.

This soil is all under cultivation, and the same crops are grown as on the adjacent Clinton and Tama uplands. Crop yields are very much the same as those secured on the Clinton soils. The type is in need of drainage primarily if it is to be made satisfactorily productive and it will respond profitably to applications of farm manure or the use of leguminous green manures. It is acid in reaction and should be limed, and phosphorus fertilizers will undoubtedly prove of value.

TERRACE SOILS

There are eight terrace types in the county, classified in the Bremer, Waukesha, Jackson, Calhoun, Buckner, Judson and Plainfield series. These types

Fig. 11—Highway thru level area of Grundy silt loam.

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are all minor in area and together they cover only 5.0 percent of the total area of the county.

BREMER SILT LOAM (88)

The Bremer silt loam is the most extensive terrace type, covering 2.0 percent of the area of the county. It occurs on low terraces along many of the streams in the county, being most extensively developed along the Des Moines river There are other considerable areas, however, along the North Skunk river and along the South Skunk river. The largest individual area is found along the Des Moines river southwest of Fosterdale. Other areas somewhat smaller are found south of Bolton, two miles north and east of Leighton along the South Skunk river and northwest of Indianapolis along the North Skunk river. There are many smaller areas along the rivers of the county and also in the vicinity of many of the smaller creeks.

The surface soil of the Bremer silt loam is a very dark brown, smooth, uniform silt loam to a depth of 10 to 12 inches. The surface soil is black heavy silty clay loam grading into a heavy tenacious clay dark brown to black in color, and mottled with drab and yellow in the lower parts of the three-foot section. A few variations from the typical soil have been included owing to their small extent. In the area south of Fosterdale small areas of the Bremer loam are included in the type as they were too small to separate on the map. The topography of the type is level to slightly undulating and owing to its position and heavy subsoil condition, drainage is generally poor.

Nearly all of the Bremer silt loam is under cultivation, corn, oats, and hay being the principal crops grown. Yields of all these crops are quite generally satisfactory when the type is drained, and it is considered a highly productive soil. The first treatment needed in many instances is the installation of tile to insure adequate drainage. The soil will respond to application of farm manure, and it should receive additions of lime as it is always acid in reaction. The phosphorus content is not high and applications of phosphorus fertilizers would undoubtedly be of value.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is the second largest terrace type in the county, covering 1.4 percent of the total area. It occurs in numerous areas in the county being most extensively developed along the Des Moines river and along the North Skunk river. The largest areas are found northeast of Lakonta in the vicinity of Bolton and three miles northwest of Indianapolis. Numerous other small areas are found along the rivers and creeks of the county.

The surface soil of the Waukesha silt loam is a dark brown to black friable silt loam 10 to 12 inches in depth. At this point it changes to a light brown silt loam grading gradually to a somewhat lighter, heavy silty clay loam at the lower depths. There are small patches of Waukesha loam, a dark brown to black loam included with the silt loam because of their small area. These patches of the loam are found in the areas of silt loam mapped a mile and a half and two miles and a half southeast of Bolton and south of Fosterdale. In these areas the sur-

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face soil is distinctly loamy while the subsoil contains more or less coarse material, the amount increasing at the lower depths. A few small areas have been included with the type where the subsoil is much lighter textured than typical. In topography the Waukesha silt loam is level to slightly undulating. Drainage is usually very satisfactory.

Practically all of the type is under cultivation and all the general farm crops are grown. Corn yields about 45 to 50 bushels per acre and in general yields of all crops are about the same as on the better upland soils. This type may be made more productive by better methods of soil treatment. Applications of farm manure are very desirable and bring about large effects on crop yields. Leguminous green manure crops may also be used profitably in some cases. The type is acid in reaction and should be limed for the best growth of legumes. It is not high in phosphorus and applications of phosphorus fertilizers would be of value in many cases.

JACKSON SILT LOAM (81)

The Jackson silt loam is a minor type in the county, covering 0.8 percent of the total area. It is found in several small areas in the county on the terraces of the Des Moines, North Skunk and South Skunk rivers and Muchakinock and Middle creeks. Areas are also found along some of the smaller streams of the county. All of the areas of this type are small in extent.

The surface soil of the Jackson silt loam is a light brown to dark brown silt loam 10 to 12 inches in depth. The upper subsoil is a light brown heavy silt loam streaked with gray. The lower subsoil is a brown heavy silty clay loam mottled with yellow and gray. Within the type there are included a few small areas of soil varying somewhat in color and texture. In some places along the uplands sandy materials have been washed over the type, forming narrow strips of a darker colored soil. These variations from the typical soil are included with the type because of their small extent. In topography the soil is level to slightly undulating and drainage is usually quite adequate.

The greater part of the type is under cultivation, general farm crops being grown. Corn yields from 40 to 45 bushels per acre while oats, wheat, timothy and clover give satisfactory yields. Fruits, small fruits and garden crops are also grown on this type to some extent, chiefly for home consumption.

The Jackson silt loam is a rather productive type but crop yields may be increased considerably thru applications of various fertilizing materials. The use of farm manure is very desirable and liberal applications should be made Leguminous green manure crops may often be used with very beneficial effects. The type is acid and in need of lime. It is low in phosphorus and applications of phosphorus fertilizers will undoubtedly prove profitable.

CALHOUN SILT LOAM (42)

The Calhoun silt loam is a minor type in the county, covering but 0.2 percent of the total area. It is found in small areas along the streams of the county, most of the areas being along the North Skunk river and Muchakinock creek. There are other areas, however, on the terraces along some of the other streams.

The surface soil of the Calhoun silt loam is a smooth, velvety, gray to gray-

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ish-brown silt loam, 7 to 10 inches in depth. Below this it grades into a light silty layer, white or gray in color, usually mottled with brown iron stains. This layer varies somewhat in thickness but generally extends to about 18 inches, at which point it passes into a tough, hard, impervious clay subsoil, grayish-brown to brown in color usually mottled with yellow and drab. In topography the soil is level and due to this fact and to the heavy impervious subsoil, the drainage of the type is poor.

The soil is practically all under cultivation, general farm crops being grown. Corn, oats, wheat and hay are produced most extensively. Yields secured on the Calhoun silt loam are very much the same as on the upland Clinton silt loam and crops may be increased considerably by applications of fertilizing materials. Liberal amounts of farm manure should be applied and leguminous green manures should be used. The type is acid and in need of lime. Phosphorus fertilizers would undoubtedly prove of value. The first treatment the soil should receive before any fertilization is practiced, however, is the installation of an adequate drainage system.

BREMER SILTY CLAY LOAM (43)

The Bremer silty clay loam is a very minor type in the county, covering 0.2 percent of the total area. It occurs in small scattered areas along some of the streams of the county, being found chiefly along the North Skunk river and the Des Moines river.

The surface soil of the type is a black silty clay loam 6 to 8 inches in depth. Below this it grades into a dark brown or black heavy, compact, dense clay, somewhat lighter in color and mottled with dark drab and yellow. The topography of the soil is level and the drainage is poor.

About 50 percent of the type is under cultivation, corn being the principal crop grown, followed by oats, wheat and timothy. The soil is particularly in need of drainage to be made more productive. Altho the yields secured at the present time are fairly satisfactory, applications of various fertilizing materials will bring about larger effects. Small amounts of manure prove profitable. Applications of lime are needed and phosphorus fertilizers will undoubtedly prove of value.

BUCKNER LOAM (38)

The Buckner loam is a minor type in the county, covering 0.2 percent of the total area. It occurs in small areas chiefly along the Des Moines river, the largest area being found south of Fosterdale. Other smaller areas occur along the Des Moines river and some of the tributary streams.

The surface soil of the Buckner loam is 10 to 15 inches in depth and consists of a brown, loose structured loam. The subsoil is a dark brown loam becoming heavier in texture at the lower depths, grading into a silt loam or clay loam at 3 feet. In some places the soil varies little in color or texture thruout the soil section. In topography the type is level to gently sloping and drainage is usually quite satisfactory. There seems to be some relation between the topographic condition and the texture of the soil. In the depressions there is less sand while the elevations seem to contain slightly more sand.

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Most of the type is under cultivation and corn, oats, hay and melons are the principal crops grown. Some vegetables and small fruits are produced for local use. Corn yields 30 to 50 bushels per acre and oats 20 to 35 bushels. This type is fairly productive but may be increased in producing power by proper treatments. It is low in organic matter and should receive liberal applications of farm manure and leguminous green manures. It is acid in reaction and should be limed. Phosphorus fertilizers would undoubtedly prove of value. Where vegetables or truck crops are grown complete fertilizers made up to favor the particular crop may often be applied with profit.

JUDSON SILT LOAM (131)

The Judson silt loam is of very minor importance in the county, covering 0.1 percent of the total area. It occurs in small areas along the Des Moines river and its tributaries, the largest area being south of Bolton along the river.

The surface soil of the Judson silt loam is dark brown in color and extends to a depth of 10 to 12 inches. The subsoil differs very little from the surface except that it is somewhat lighter in color. In topography it is slightly undulating and drainage is fair.

Practically all of the type is under cultivation. Corn, oats, timothy and clover are the principal crops grown. Corn is the most important crop, yielding 30 to 75 bushels per acre. Oats yield 20 to 35 bushels and hay 1 to 1½ tons per acre. This type is quite productive but can be improved in many cases thru proper drainage. Applications of farm manure are of value, lime is needed as the soil is acid, and phosphorous fertilizers will undoubtedly prove of value.

PLAINFIELD LOAMY FINE SAND (118)

The Plainfield loamy fine sand is a very minor type in the county, covering only 0.1 percent of the total area. It is found in two areas, one occupied partly by the city of Eddyville on the Wapello county line and the other north and west of Eddyville along the Des Moines river.

The surface soil of the type is a dark brown loamy fine sand, underlain at 12 to 15 inches by a light brown sand. With increasing depth the soil becomes lighter in color and coarser in texture. In topography the type is level, drainage is adequate to excessive.

The type is of little agricultural importance. That part of it not occupied by the town of Eddyville is used for the growing of watermelons, cantaloupes, truck crops and berries. When so utilized the type should receive liberal applications of farm manure or leguminous green manures. Fertilizing materials would be of value on the type, and complete brands particularly prepared for special truck crops may often give desirable effects.

SWAMP AND BOTTOMLAND SOILS

There are six swamp and bottomland soils in the county and these together with the colluvial phase of the Wabash silt loam and the area of riverwash make a total of eight areas of swamp and bottomland. The soils are classified in the Wabash, Genesee and Sarpy series and together they cover 12.9 percent of the total area of the county.

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WABASH SILT LOAM (26)

The Wabash silt loam is the most extensive bottomland soil in the county. With the colluvial phase, which is minor in area, it covers 9.2 percent of the total area of the county. It is developed most extensively along the North and South Skunk rivers and the largest individual areas occur along the South Skunk river in the northwestern quarter of the county. Smaller areas of the type are found along the Des Moines river, Buckley, Middle, Cedar, Muchakinock and St. Joseph creeks and along many of the smaller streams.

The surface soil of the type is a dark brown to black silt loam usually 10 to 14 inches in depth. The upper subsoil is dark brown to black and generally somewhat heavier in texture. The lower subsoil is a drab or yellowish-gray clay loam mottled with brown. Near stream beds, pockets or layers of sand are frequently encountered. Small areas of a light brown silt loam and a brown sandy or fine sandy loam are included within the type as they are too small to separate on the map. These variations from the typical soil are most frequently encountered near the streams. In those areas where the type is associated with the Wabash silty clay loam there is a gradual change from the one type to the other and the boundary lines must frequently be drawn arbitrarily. In topography the soil is level and the drainage is poorly developed.

The type is subject to overflow and hence only a portion of it is under cultivation. The tree growth which occurs mainly near the stream channels, consists of oak, maple, elm, hickory and ash. On the cultivated areas corn, wheat, oats and hay are produced. Corn yields 25 to 85 bushels, oats 20 to 40 bushels, the larger yields being obtained under favorable seasonal conditions. Blue grass does well and the major portion of the type is utilized for pasture for cattle, sheep and hogs.

The Wabash silt loam is a relatively productive type and when protected from overflow and well drained, crop yields are very satisfactory. These treatments are, however, fundamentally necessary on this soil. Small applications of farm manure prove of value on the cultivated areas, the soil is acid and in need of lime and phosphorus fertilizers would undoubtedly prove of value.

WABASH SILT LOAM (COLLUVIAL PHASE) (26a)

The colluvial phase of the Wabash silt loam is minor in area in the county, covering 2.2 percent of the total area. It occurs in narrow V-shaped valleys along many of the smaller streams of the county and it is also found in narrow areas along the outer boundaries of the valleys along some of the larger streams. It is made up mainly of material washed down from the adjacent uplands and deposited over the bottomland.

The surface soil of this phase is a dark brown to black silt loam 10 to 12 inches in depth. The subsoil is a black, heavy silt loam to light silty clay loam extending to a depth of 20 to 24 inches and resting upon a coal black silty clay loam to clay. Occasionally the subsurface soil is streaked with brown and gray. There are some variations in texture in the soil, but it is predominantly a silt loam. Drainage is fairly well developed except in a few instances.

Only a small portion of the type is under cultivation and it is not important agriculturally. On the cultivated areas corn and hay give excellent yields. The

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type is largely used for pasture and is most desirable for that purpose. When cultivated the soil is in need sometimes of drainage and occasionally of protection from erosion. It will be made more productive by applications of farm manure, it is acid and needs lime, particularly for legume growth and it will undoubtedly respond to applications of phosphorus fertilizers.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the second largest bottomland soil in the county, covering 1.9 percent of the total area of the county. It occurs in many areas along the North and South Skunk rivers and the Des Moines river. The largest areas are found along the South Skunk river. Many smaller areas are found associated with the Wabash silt loam along some of the smaller streams.

The surface soil of this type is a dark brown to black friable silty clay loam 6 to 10 inches in depth. There is a very little change in color or texture between 10 and 20 inches, at which point there is a slight mottling with drab and rusty brown. At lower depths the sub-soil is a dark drab plastic clay mottled with brown and gray. Included within this type there are small areas of Wabash clay, a crumbly to granular black silty clay loam to clay underlain by a heavy, dark drab, sticky, waxy clay. These areas are not separated on the map because of their small extent. The type is level to flat in topography. It is poorly drained and subject to overflow.

Only a small portion of the type is under cultivation. Corn, oats, wheat, and hay occupy the cultivated areas. Blue grass does well and serves for pasture. The soil is naturally productive and when well drained, protected from overflow and properly handled crop yields are quite satisfactory. It should not be plowed when too wet or too dry as in either case the physical condition of the soil is not satisfactory. When used for cultivated crops it should be manured and limed and it probably would also respond to phosphorus fertilizers.

GENESEE SILT LOAM (71)

The Genesee silt loam is a minor type in the county, covering 0.8 percent of the total area. It occurs mainly along the Des Moines river altho small areas are found also along the North and South Skunk rivers and some of the minor streams of the county. The larger individual areas occur one and one-third miles southeast of Bellefontaine, two and one-half miles south of Givin and along Bluff creek from Lakonta to the Des Moines river.

The surface soil of the Genesee silt loam is a grayish-brown to light brown silt loam. When wet the surface is brown in color. The surface soil extends to a depth of 6 to 12 inches changing at that point to a slightly lighter colored soil, sometimes a silt loam in texture but usually a light silty clay loam. Generally the texture becomes somewhat heavier at the lower depths. A few areas of Genesee silty clay loam are included with the Genesee silt loam because of their small extent. These areas of the heavier textured type are located on the west side of Muchakinock creek where it empties into the Des Moines river, one mile north of Bellefontaine and in areas southeast of Bellfontaine along the Des Moines river. The soil is flat in topography but is usually well drained. It is subject to frequent overflow.

The greater part of the soil is under cultivation and is utilized mainly for

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corn, oats and hay. Corn yields 25 to 75 bushels per acre, oats 20 to 40 and hay one to two tons. When utilized for general farm crops the soil should be protected from overflow. When this is accomplished it will respond to liberal applications of farm manure, the application of lime and treatment with a phosphorus fertilizer. Crop yields may be increased by these treatments and the soil made more productive.

SARPY SILT LOAM (89)

The Sarpy silt loam is a minor type in the county covering 0.6 percent of the total area. It occurs chiefly along the Des Moines river northwest and southeast of Bellefontaine, one and one-half miles west of Fosterdale and one and one-half miles west and northwest of Eddyville. A few small areas are mapped along the North and South Skunk rivers.

The surface soil of the Sarpy silt loam is a brown silt loam having a uniform smooth texture extending to a depth of 12 to 14 inches. The subsoil is generally a light brown loam, loamy sand or fine sand. Occasionally small patches of a heavy textured Sarpy soil are found and these have been included with the silt loam because of their small extent. In topography the type varies from level to slightly undulating, occasionally being marked by low sandy ridges or by depressions in which the soil is somewhat heavier in texture. Drainage is well established. The type is subject to overflow, however, and to be utilized satisfactorily for cultivated crops must be protected from overflow.

Corn is the chief crop grown altho oats, timothy, alfalfa and clover are produced to some extent. Melons and truck crops are grown in some instances. A portion of the type is used for pasture. When cultivated this soil would respond to applications of farm manure and lime. It should undoubtedly receive phosphorus fertilizers also.

SARPY LOAM (91)

The Sarpy loam is a minor type in the county, covering 0.2 percent of the total area. It occurs mainly in small areas along the Des Moines river, the largest area being found a mile and a half south of Bolton.

The surface soil of the Sarpy loam is brown in color and it extends to a depth of 8 to 12 inches. The subsoil is a brown loamy fine sand. The areas are quite variable in texture and patches of loamy fine sand, fine sand and silt loam too small to separate out are included with the type. The prevailing texture is a loam. In topography the soil is level to slightly undulating. Some ridges are present. Drainage is quite satisfactory.

The type is not important agriculturally but it produces excellent yields of the common crops. Melons and other truck crops are particularly suited to this soil. When protected from overflow, crop yields may be quite satisfactory. The type will respond to treatments with farm manure and lime and probably also phosphorus fertilizers.

SARPY FINE SANDY LOAM (102)

This is a minor type in the county, covering 0.1 percent of the total area. It occurs in small areas along the Des Moines river and the North and South Skunk rivers. The largest occurrence is near the Marion county line north of Bellefontaine.

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The surface soil of this type is a light brown to brown fine sandy loam extending to a depth of 8 to 15 inches. The texture of the surface soil is quite variable, ranging from a fine sand to a silt loam. Owing to their small extent these variations in texture could not be separated on the map. The subsoil is a brown loamy fine sand to fine sandy loam. Within the type there are included small areas of sand "blows" which consist of fine sand. These were too small to show on the map. In topography the type is almost level and drainage is quite adequate.

Probably about 50 percent of the soil is under cultivation, general crops being grown successfully. Melons and other truck crops could probably be grown very satisfactorily on this type. Crop yields may be increased on this soil thru liberal applications of farm manure, the use of lime and the application of phosphorus fertilizers. For truck crops complete brands of fertilizers may be used with profit. To insure satisfactory crops the soil should be protected from overflow.

RIVERWASH (53)

There is a small area of riverwash in the county, amounting to 0.1 percent of the total area of the county. It occurs along the Des Moines river and is subject to frequent overflow. It consists mainly of heaps of loose fine sand, sand banks and low-lying sandbars. It is usually a grayish-brown to gray sand, varying widely in texture. Gravel occurs in some areas. The material is practically non-agricultural. Occasionally a sparse growth of brush, willow and grasses occurs on it.

RESIDUAL SOIL

There is one residual soil in the county mapped as the Union silt loam. It is minor in extent, covering 1.2 percent of the total area.

UNION SILT LOAM (157)

The Union silt loam occurs mainly in the southwestern portion of the county in association with the Clinton and Lindley silt loams. It is found in narrow bands along deep drainageways, ravines and steep slopes. Most of the areas are found along North Coal, South Coal, Turkey Run, Little Bluff and Bluff creeks.

The surface soil of the Union silt loam is brown in color extending to a depth of 6 to 8 inches. The subsoil is a brown to gray or drab silty clay loam to clay splotched with yellow, brown and various shades of red. It contains fragments of limestone, shale and some sandstone. In many places the bed rock is reached within the three-foot section. The type is quite variable and in some places the surface soil is a silty clay loam while in others it is quite sandy. The boundary line between this soil and the Clinton and Lindley silt loams is frequently established rather arbitrarily as there is a gradual change from the one type to the others.

The soil is not important agriculturally and practically none of it is under cultivation. In topography it is rough and much of it has been very extensively eroded. It is largely forested with oak, hickory, hazel and other trees and shrubs.

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APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in co-operation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and to insure the best crop production.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced", as in market gardening, some nitrogenous fertilizers may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils, This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the

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soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in the soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the ni-

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TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate ($NaNO_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nit'g'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay	3 T.	120	15	90	19.20	1.80	5 40	16.40

trogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops procured are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the

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state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until the crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for lack of water necessary to bring them their food and also for lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of heavy drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holdng power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil,climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes

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in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the

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soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exceptions to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas are likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 12.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a

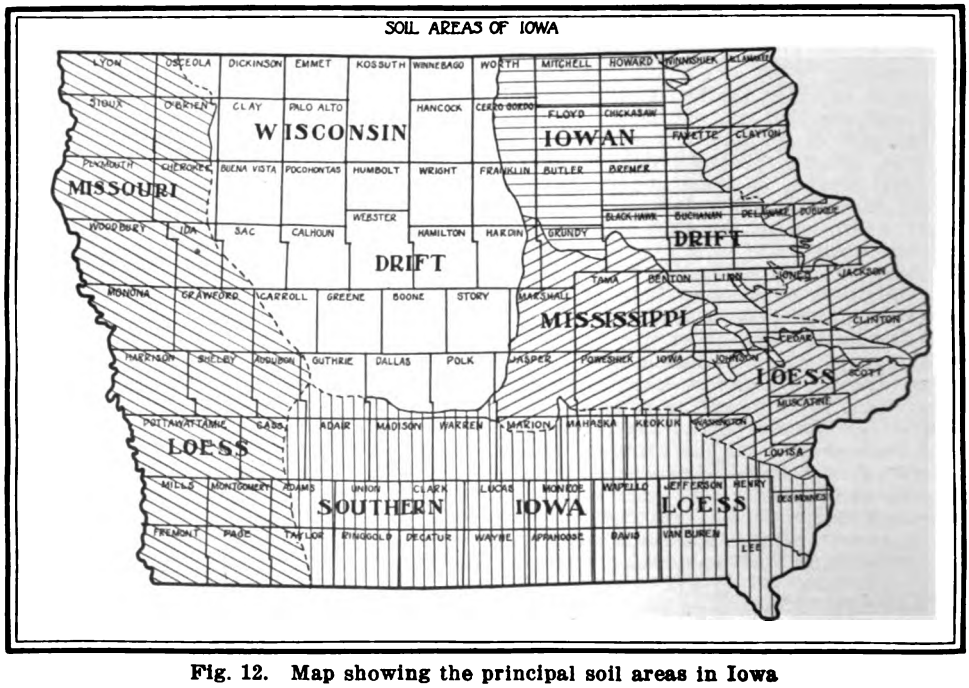

Fig. 12. Map showing the principal soil areas in Iowa

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period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been wel enumerated by the Illinois Experiment Station in its Soil Report No. 1.
They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter	All partially destroyed or undecomposed vegetable and animal material.
Inorganic matter	Stones—over 32 mm.* Gravel—32—2 0 mm. Very coarse sand—2.0—1.0 mm. Coarse sand—1.0—0.5 mm. Medium sand—0.5—0.25 mm. Fine sand—0.25—0.10 mm. Very fine sand—0.10—0 05 mm. Silt—0.05—0.00 mm.

*25 mm. equals 1 in. †Bureau of Soils Field Book. ‡Loc. cit.

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SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 per cent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 per cent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 per cent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 per cent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.

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